The Imperial College of Tropical Agriculture

Trinidad, British West Indies

SUGAR: WITH SPECIAL REFERENCE TO THE WORK OF THE COLLEGE

A Supplement to
"Tropical Agriculture"
September, 1927.

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SUPPLEMENT TO "TROPICAL AGRICULTURE."

COLLEGE COURSES WITH SPECIAL REFERENCE TO SUGAR PRODUCTION.

BY

G. EVANS, C.I.E., M.A.,

Principal of the Imperial College of Tropical Agriculture.

IN this article it is proposed to describe briefly the system of training that is adopted at the Imperial College of Tropical Agriculture, Trinidad, for students in Sugar Technology. At the same time mention will be made of the courses of study that are now being given at this Institution and an attempt will be made to show how they are designed so as to give the student as wide and complete a training as possible.

The College is a new one, being only in its fifth year of existence and naturally the courses are being continually modified and improved each year as experience indicates. It is necessary to explain in the first place that three classes of students are at present catered for at the College. They are :—

(1) Diploma students.
(2) Post-graduate.
(3) Special students.

The qualification for admission to the Diploma course is the Matriculation of any University within the British Empire or its recognised equivalent. Unless the applicant has actually matriculated or has secured a suitable School Certificate he should submit evidence that the qualification he possesses is accepted by a University of the British Empire as the equivalent of the Matriculation of that University.

The Diploma course lasts three years and students who qualify by examination at the end of the third year are awarded the Diploma of the College.

After completing his Diploma course a student may stay on a fourth year and specialise in some subject, such as Sugar Technology.

Qualification for admission to the post-graduate courses is the possession of a degree or diploma of any British University, University College or other Academic Institution specially approved by the Governing Body.

The Associateship of the Imperial College of Tropical Agriculture is awarded to fourth year and post graduate students on condition that they attend certain courses of lectures decided on by their Tutors and pass the necessary examinations. They are also required to undertake some special piece of investigational work and to write a dissertation at the end of the period on the experimental results they may have attained.

Special students are allowed to attend the College provided the College authorities are satisfied that they possess qualifications that enable them to benefit from the courses they attend. Some of these students come to avail themselves of the special facilities offered by the College for research in some particular branch. Others come for a short period for a general "refresher" course or to acquire knowledge in some particular branch. A certificate of attendance only is granted to special students of this nature.

As several of the Diploma students, in particular, are staying on a fourth year, and specialising in Sugar Technology with a view to gaining the College Associateship, it may be interesting to mention the system of training provided for a student of this class and to enumerate some of the classes he attends.

As a rule a Diploma student makes up his mind at the end of his first or during his second year at the College that he wishes to specialise in sugar and his course of training is then decided on and the necessary bias applied.

The first year course deals with elementary principles of agriculture, botany, chemistry, economics and zoology, and the student is given a preparatory introduction to the general principles of agricultural practice and of the associated sciences. At the agricultural lectures he learns something about the soil and the underlying principles that are concerned in its management in relation to the crops grown. He undergoes a good deal of practical work in the field and also takes a course on plant propagation and general nursery work on the culture of economic plants. A course on animal husbandry and a general survey of farm livestock including their feeding, management and general care is also included.

Similarly in botany the course is elementary in nature and aims at giving the student an insight into the morphology, anatomy, and physiology of plants and generally enabling him to get a glimmering into some of the problems involved in the mysteries of plant growth. In Chemistry the student goes through a course on elementary inorganic chemistry and elementary physics. The preparatory course for economics is concerned with mathematics, elementary statistics, economic history and geography. He also acquires a knowledge of the structure and physiology of animals by attending the Veterinary lectures, and, in the Department of Entomology learns something about the life history and habits of insects.

The first year's studies are, it will be observed, devoted to the acquisition of elementary knowledge in agriculture and its cognate sciences and are in the nature of a " try out " for the student.

Having successfully passed the first year examination the student in his second year undertakes a more detailed study of the subjects. In Agriculture he begins a careful study of the more important economic crops from the cultural point of view and the same range of crops is covered in his botany lectures. In chemistry he begins a detailed study of the soil and learns how to examine soils in a simple way both in the field and in the laboratory. He further learns the principles that underlie the successful application of manures and fertilizers. In the realm of Economics he is taught the scope and meaning of statistics and how to study tropical statistical data and the methods of accountancy. In this year he also takes a full course in Entomology and learns not only the chief insect pests of tropical crops but also the best methods of dealing with them.

The second year student as a rule also attends a course of lectures in Veterinary science but to a man who has already decided to specialise eventually in Sugar Technology a course on elementary colloid science is substituted. In this course he gains an insight into the general properties and classification of colloidal substances and into the meaning of diffusion, analysis, and ultra-filtration. He carries out experiments in this branch of science and studies the methods of preparation of colloids.

In the third year the student begins to specialize in Sugar Technology and breaks away further from the standard Diploma course in general agriculture. With the other students, however, he attends a brief, but essential, course in hygiene and tropical sanitation as it is recognised that some knowledge of tropical diseases and their methods of prevention and control is very necessary to every man who intends to devote most of his life to work in the tropics. His further studies of economics also follow those of the general students and include a survey of estate and factory organization and marketing, administration and economic theory, which should undoubtedly prove useful to him in his future career.

In Chemistry, however, in addition to an advanced course in analytical methods and a series of lectures in the manufacture of crop products, he specialises in Crop Ecology and studies the soil, the atmosphere, and the plant in relation to each other; such matters as soil acidity, the structure of the soil, and plant residues also receive special attention.

There is a special course in the micro-biology of the sugar factory and the distillery.

In his third year the student also begins a detailed study of technology, which includes a course on chemical machinery comprising the principles involved in the employment of boilers, pumps, vacuum evaporators, centrifugals and other units of the factory. Another course is devoted to Sugar Technology and deals with such subjects as juice extraction, clarification, filtration, crystallization, &c., the grading and handling of sugar, factory bye-products and factory management. The chemistry of the factory is also taught and the importance of routine chemical analysis as an aid to factory control is emphasized.

The beautifully equipped College Sugar Factory affords ample means for practical work and in fact during the present year the greater part of the routine analyses were undertaken by the technological students during the crop season and they were also taught how to keep analysis registers, and the elaboration of factory reports.

The fourth year, constitutes an extension of the third year course in Sugar Technology with practical work in the factory itself. Students in this year take their turn in the factory organisation and are also encouraged to undertake research and investigational work and are given special facilities on occasion to visit one or other of the big commercial factories in the neighbourhood of the College. The Managers of these concerns have always proved most helpful in this way.

So far, most of the men who have taken the Sugar Technology course at the College are Diploma students, but an exceptional opportunity is obviously afforded to post-graduate students to attend. Such men would be well advised to attend the third year course in technology outlined above, as it is an introductory course, and to study for a final year in order to gain factory experience.

In conclusion, it is hoped that the brief survey given in this note will suffice to draw attention to the exceptional facilities that exist at the Imperial College of Tropical Agriculture for training and research in Sugar Technology.

The College Experimental Factory.

THE COLLEGE SUGAR FACTORY.

The Conception of the Factory and its History up to the Time of Opening.

BY

G. WRIGHT, B.COM.,
Lecturer in Economics.

SUGAR-CANE was introduced into the West Indies shortly after their discovery by Columbus and subsequently the economic progress of the region was particularly bound up with the production of muscovado sugar. In the nineteenth century, factors such as the abolition of slavery—in itself an admirable measure—the growing competition of beet sugar, and governmental neglect, offset to a large extent the natural advantages of the West Indies for sugar production. From these contributory causes affairs were in a parlous condition at the end of the century, and the West Indies, which were in the eighteenth century the chief source of the sugar supply of the United Kingdom, had become of relatively little importance. Later, however, the results of the Brussels Convention, together with the establishment of central factories and the world wide increase in the demand for sugar, made the outlook more encouraging.

The importance of sugar was realised during the Great War, and increasing attention was paid to the development of Empire resources. In this development, the West Indies took an important step when a sugar school with a demonstrational and experimental factory was established as an important feature of the West Indian Agricultural College which later became the Imperial College of Tropical Agriculture. This was definitely the first institution giving adequate theoretic and practical instruction to be established in the British Empire. The importance of organised research and education with regard to sugar has, however, long been recognised, and schools and experimental stations were in existence in other parts of the world, but, with the exception of the courses at the Sugar Experiment Station at Audubon Park, the training was largely of a theoretic character and students of British origin were compelled to gain their practical training outside the Empire. Consequently but few young men took up the study of sugar manufacture, and the supply of responsible and well trained sugar technologists for Empire projects was entirely inadequate. The need for a complete sugar school within the Empire was clear.

The history of the College Sugar Factory may almost be taken back to the Imperial Department of Agriculture which was established by the Colonial Office in 1898 with the twofold object of restoring the sugar industry of the West Indies and of encouraging other industries. Under the able guidance of Sir Daniel Morris and later of Sir Francis Watts and with the help of a competent staff of able assistants, much valuable work was done and the practical worth of applied science aptly demonstrated to the planting community. When, as a result of the resolutions of West Indian planters and the report of the Tropical Agricultural Committee, a College was founded on the 2nd September, 1921, the staff of the Imperial Department became the professors and their head, Sir Francis Watts, became the Principal. The object of the College was to provide the agriculturist of the warmer regions of the globe, not only in the West Indies, but in all tropical areas of the Empire—and indeed outside the Empire—with a sound modern and scientific training. In addition, bearing in mind the need for adequate training in sugar manufacture and the particular suitability of the West Indies as a centre for this training, a well planned and equipped course in sugar technology was one of the important features in the curriculum of the new institution.

The idea of a college of agriculture for the tropics giving special attention to sugar was an early conception, but amongst those who formulated the ideas and pursued them with the persistency that has been so successful, special mention must be made of Sir Francis Watts and Mr. George Moody Stuart. The ground was broken by them, and later, when their suggestions were becoming tangible, most valuable assistance was given on the sugar side by the late Mr. Claude Berthon, who was responsible for the design of the present factory.

That the projected college should be a concern of the Empire and that it should have a council composed of representatives of the different Universities had been suggested in correspondence between Sir Francis and Mr. Moody Stuart as early as 1917 as an outcome of still earlier proposals, while in the same year Sir Francis wrote, " I think it should be possible . . . to get together a committee of those interested in sugar to discuss general proposals on the lines of establishing a School of Sugar Technology in the Tropics to be worked in conjunction with British Universities and Technical Schools, the idea being that the students may pursue their studies in chemistry,

physics, engineering and similar matters in one of the home institutions and then come out for a one or two years course in sugar technology in a sugar country."

The war and its aftermath prevented very definite steps being taken, but with the establishment in 1919 of a Tropical Agricultural Committee, the subject was taken up again and in response to a request from Mr. Stuart, Sir Francis in January, 1921, communicated a general scheme for a model sugar factory. In forwarding with his own suggestions a few notes about the Audubon Factory prepared by Mr. Dunlop, Sir Francis wrote "I incline to the view that the mill should be capable of grinding two tons per hour . . . the arrangement need not depart in any marked degree from that of an ordinary factory." He also points out that there should be ample space both for teaching purposes and for the addition of extra appliances.

By this time the Governing Body of the projected College had been constituted and it was suggested that they should invite the chief manufacturers of sugar machinery to form a committee to consider the question and draw up plans. As a result, a meeting of representatives of the leading sugar machinery manufacturers was arranged for Tuesday, 14th June, 1921, at the Royal Technical College, Glasgow. Prior to this meeting Mr. Berthon had been consulted and he prepared an arrangement sketch of the factory and got out the list of the required machinery which was circulated to those attending the meeting.

At the Glasgow conference, Sir Francis Watts and Mr. Berthon explained what had been done with regard to the establishment of the College and pointed out the scope which it offered for a sugar school with a model factory for teaching purposes. Pointing out that such a factory should be large enough to grind sugar cane on a working scale at the rate of about two tons per hour—a factor deciding the sizes of the appliances to be installed—they appealed to the firms represented to give the scheme their generous support. In the useful discussion which took place, it was made evident that the proposals had been received favourably. Although several representatives had, of course, to refer to their directors, a few were able to make definite or conditional promises, and, in the course of discussions, offers were made on behalf of several firms to supply an eleven-roller milling plant, centrifugals, crystallisers, a water tube boiler, filter presses, mud tanks, contributions to electrical equipment, pump equipment and steel structural work. The success of the meeting, largely due to the efforts of Sir Francis Watts, Mr. Moody Stuart, Mr. Berthon and Mr. W. Scott Herriot, together with the co-operation of the sugar machinery manufacturers, meant that the long contemplated experimental sugar factory might be regarded as definitely assured. The College commenced as a teaching institution in October, 1922, but, unfortunately, the scheme for the building of a sugar factory had to remain in abeyance for a short time. In June of 1922, however, as an outcome of deliberations with Mr. Scott Herriot, Mr. Berthon prepared a design allowing for the making of 96° sugar, yellow crystals and white sugar. This was circulated amongst the machinery manufacturers who had promised to contribute parts in order that they might proceed with their design and manufacture. In Trinidad a site was being selected and Sir Francis Watts' suggestion of the triangle formed by the junction of the Trinidad Government Railway lines at Curepe was adopted.

Prints of the proposed general arrangement together with diagrams of operations prepared by Mr. T. H. P. Heriot were sent to Trinidad in January, 1923 and submitted to the criticism of Mr. Thornton and Mr. W. Scott, chief engineer and chief chemist respectively at the Usine Ste. Madeleine, Trinidad, who along with Sir Francis Watts made several suggestions dictated by local conditions. In June, 1923, a recommendation that the erection of the Model Sugar Factory be proceeded with, was adopted at the twelfth meeting of the Governing Body and notification was received in Trinidad. Detailed plans were then drawn up by Mr. Mayes, once Engineer of Diamond, Demerara, who had been loaned to Mr. Berthon by The Mirlees Watson Company, Ltd., at the instance of Mr. Herriot, and it was later arranged that he should proceed to Trinidad to take charge of the erection of the factory. The various problems arising in the course of erection—water supply, transport services, &c.—were all satisfactorily dealt with, and in the course of his work, Mr. Mayes was assisted by Mr. C. T. Watts, Technical Assistant to the Principal, who had an intimate knowledge of local conditions and labour supply. Mr. Mayes left Trinidad to take up the post of Engineer in Charge of the Basseterre Sugar Factory, St. Kitts, in January, 1925, and the factory was completed shortly after under the direction of Mr. Watts.

It was thought fitting that the first season of the factory should be recognised by an inaugural ceremony and on Saturday afternoon, 28th February, 1925, His Excellency Sir H. A. Byatt, K.C.M.G., Governor of Trinidad and Tobago officially opened the factory.

Members of the Sugar Manufacturers Association, the Agricultural Society and the Chamber of Commerce and other interested gentlemen were present at the opening, but it was generally felt to be most unfortunate that Sir Francis Watts who was so largely responsible for the conception and realisation of the factory, was prevented from attending owing to absence from the Colony on official duty. At the ceremony the mill was stopped for a short period and speeches were delivered by the Principal, Dr. H. M. Leake, by Mr. E. A. Robinson, Professor Farmer and His Excellency the Governor, Sir H. A. Byatt

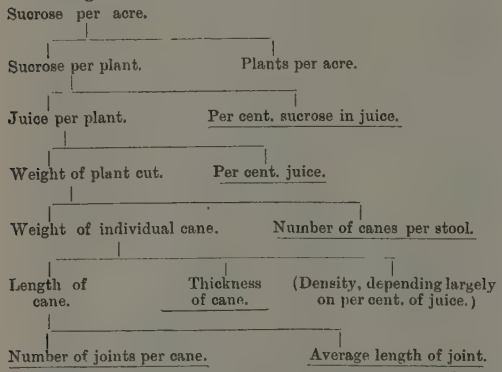
who said "that notwithstanding the fact that the output of sugar from the British Empire now reaches four and a half million tons annually, no provision has hitherto been made at any University or College in the Empire for giving men a training in the chemistry and technology of the processes involved in its manufacture . . . The opening of the model sugar factory . . . therefore marks an important advance . . . That the importance of this project has appealed to the sugar industry at home . . . is evident from the fact that nearly all the machinery in this factory, amounting to no less than £20,000 in value, has been supplied as a gift by firms belonging to the British Sugar Machinery Manufacturers' Association, and the warm thanks of the College are due to those firms for their generosity, which has rendered the equipment of the factory possible . . . The work of the College is of Imperial importance since the full utilisation of the products of the tropical dependencies of the Empire is vital to its economic welfare . . . it is hoped that it will be widely recognised that the College is not primarily a Trinidadian or even a West Indian institution, but that its appeal extends to all countries of the Empire."

THE SCOPE OF GENETIC RESEARCH ON SUGAR-CANE.

E. E. CHEESMAN, B.Sc., A.R.C.S.,
Professor of Botany and Genetics.

ONE of the ways in which botanical research can undoubtedly help the sugar industry is by means of genetic analysis of existing cane varieties with a view to improvement of the methods adopted in the practical breeding of new ones.

If we adapt to sugar-cane the illuminating method of yield analysis applied by Harland (*West Indian Bulletin*, 17, pp. 145-161, 1920) to Sea Island cotton, we find that the weight of sucrose obtained per acre depends upon a number of morphological and physiological characters, of which the more important are shown in the following scheme :—


Sucrose per acre.
Sucrose per plant.
Plants per acre.
Juice per plant.
Per cent. sucrose in juice.
Weight of plant cut.
Per cent. juice.
Weight of individual cane.
Number of canes per stool.
Length of cane.
Thickness of cane.
(Density, depending largely on per cent. of juice.)
Number of joints per cane.
Average length of joint.

Thus at least six characters are involved in building up the final yield. Actually there are more, because such a character as " % sucrose in juice " is almost certainly dependent on several factors, though it is not known what these are.

The present position is that we do not know how a single one of these important characters is inherited. What we do know, is that every cane variety yet tested has proved to be a highly complex hybrid, whose characters segregate, and recombine in its seedling progeny to form a series of plants among which almost every conceivable variation occurs.

Since 1888 this range of variability in the seedling progeny of sugar-cane varieties has been very ably and profitably utilized, both in the West Indies and elsewhere, for the production of new types. As the parent varieties contain factors for qualities both good and bad, and as these segregate from each other in the processes preceding seed formation, and recombine apparently according to the laws of chance, it is to be expected that sometimes the new combinations will be better than that in the parent, and sometimes worse. Experience shows that such is the case, but that worse combinations arise very frequently and better ones very rarely. The art of cane-breeding lies, therefore, in the recognition and preservation of the rare good combinations when they occur, but the breeder can do little to influence their occurrence. He knows by experience which parents are most likely to produce valuable offspring, but is left in the dark as to why.

The time has come when an attempt must be made to breed new canes by systematic analysis of existing varieties into their good and bad components, followed by synthesis of new canes from the good with elimination of the bad.

The method by which this can be accomplished is very simple in its broad outlines, but slow, costly, and difficult in its technical details, for which reason it is proper work only for a research institution equipped with all facilities and unhampered by a necessity for quick results.

Genetic analysis of a sugar-cane variety involves first the raising of a number of self-fertilized seedlings from it, keeping for study both good and bad. From a study of these with respect to all the characters mentioned above, and the proportions in which certain types occur, much may be learnt. Self-fertilized in their turn, these seedlings will again split up into a number of types, affording further material for study. After several generations of self-fertilization, the progeny of these plants should cease to split up, and when that stage is reached the variety will have been analysed into component parts, represented by a number of different cane plants each of pure constitution. Some of these plants will have more good qualities than bad, others more bad than good ; probably none of them will have all the good qualities of the parent. But now by judicious recombination the bad qualities present in the original parent can be eliminated, and the good ones brought together into one or several really good combinations.

There can, of course, be no possible one " best " cane variety to be grown under all sorts of conditions, but it will be appreciated that with the detailed knowledge obtained during the analysing process, it should ultimately be possible to build canes " to order " to suit specific districts and conditions.

The justifications for undertaking such a complicated piece of work are, first, that the final result should be much better canes than any obtained by the " hit or miss " method, and second, that only in this way can an understanding of the constitution of sugar-canes be reached. Results obtained during the course of the work, even before its completion, should be of considerable use to the numerous stations engaged in practical breeding, but it is clear that the method itself is not one to be adopted by them in cases where they have a clear duty to provide local industries with better canes by the shortest possible way, and that for them the present technique, modified as knowledge advances, is likely to remain useful for many years to come.

SUGAR-CANE BREEDING.

A Review and a Forecast.

BY

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THE stupendous piece of work recently accomplished by Bannier, in writing up the history of the raising of cane seedlings in Java between the years 1893 and 1925, may be considered, in one sense, to mark the commencement of a new era in this line of research. And this, not so much for the value of this long drawn out and continuous record of scientific work on one subject, as in the example set to other countries, in which the same study has been carried on for years, or has only recently commenced. The raising of cane seedlings has taken a distinct step towards becoming an exact science; and it behoves all who have been engaged in this enterprise to lay bare their records and explain how they have got their results, for the benefit of the sugar industry in the tropics as a whole. The time has now passed, moreover, for the happy-go-lucky methods so long in vogue: almost every scientifically equipped sugar industry is now raising its own seedlings, and the time has come when well-considered schemes will be demanded, in place of dipping one's hands into the lucky bag.

I propose in this article to take, as my examples, the work done in Java and India, and, in doing so, lessons may be drawn therefrom as to the future policy to be adopted in all directions, and especially in the various parts of the British Empire.

Producing cane seedlings is one of the easiest of scientific experiments and can be undertaken by any amateur, but obtaining such as are fitted for any special conditions is, perhaps, one of the most difficult; while, to go a step further and raise seedlings which have a very wide range of usefulness appears to be almost an impossibility. Yet, as if some fairy desired to encourage further efforts, first trials have sometimes yielded excellent seedlings which have not been surpassed after many years of further work. With the developed technique of to-day, many desired crosses may be effected with moderate certainty, provided that the chosen parents are not sterile as to the same reproductive organs: those that are female-sterile often have abundant fertile pollen, while male-sterile forms are among the most valued mothers.

Arrowing itself can also now to a large extent be controlled, and, with appropriate agricultural treatment, cane varieties have been made to produce flowers which have never been known to do so before, while sparse yielders have been found to become surprisingly fertile with a mere change in their external conditions. In the circumstances, the astonishment evinced at the fine seedlings produced a quarter of a century ago has given place to a wonder that we are not able to produce better seedlings than we do.

The knowledge that the seed of the sugar-cane is fertile is in all probability as old as the cultivation of the plant itself. But it is extremely difficult to prove this assertion, because the earliest observers were incapable of making any records at all, and later ones had no reason to suppose that the phenomenon was of any importance when it was so easy and so much more profitable to raise the crop by cutting the canes into pieces and planting them.

Thus, the fact that the sugar-cane was habitually reproduced in nature and that new forms were constantly arising, could hardly have escaped the notice of the more intelligent inhabitants of New Guinea, considering the wealth of the new forms revealed, when first their forests were penetrated by adventurous white men who were permitted to return. Similarly, the abundant seedlings produced by the wild Saccharums on every sandy spit of the Ganges and Irrawaddy, often showing great variations among themselves, could hardly have passed unnoted by the reflective Indian cultivator. It is a common statement that, in comparatively recent times, the thicker and sweeter forms of the wild plant were sought out by the children to suck, and even crushed by their fathers to make gur. The Punjab cultivator of to-day points out the wild *kans grass*, as the ancestor of the local cultivated Katha.

Historically, on the other hand, we can only point with certainty as far back as 1858, when the fact was established that the cane arrows in the West Indies were capable of producing offspring: and to a period some thirty years later, when the re-discovery was made, and because of an

economic crisis in the industry, the possible value of this property of the sugar-cane was finally grasped.

Now, the raising of seedling canes has become almost a fine art and, it is a much more difficult enterprise than ever before. One is not content with the old slip-shod methods: a definite objective must be resolved on, and, casting aside all deviations from it, however tempting they may be, that objective must be kept in view, until a result, one way or another, is obtained, or much labour be lost. Even then, the result may be considered as not worth the trouble, but this is to take an altogether wrong point of view: experience has been gained as to the proper way of tackling the problem, and many useful pieces of work have been built up on a series of failures.

The foundation of this higher stage of seedling work was probably chiefly laid by Kobus, when he went to India to get canes which were resistant to sereh disease. He brought back a number of kinds, chiefly from the United Provinces, and grew them for several years under rigid inspection on an island before taking a chosen two to Pasoeroean in Java. Of these Chunnee was selected, and when crossed with tropical cane varieties, for a time gave very satisfactory results.

Chunnee belongs to the great Saretha group of Indian canes, which extends throughout the length and breadth of the land. The canes are fibrous and of not very good habit, but the juice is good; and we find an interesting gradation in height and thickness, as we proceed from the colder to the warmer parts of the country. Thus, it is represented at the northern limit of the Indian cane region by Katha, easily recognized by the cultivator as a relative of the wild kans grass which infests his fields (*Saccharum spontaneum*); in the United Provinces we have various forms such as Chin and Saretha, and in Bengal, the thicker Khari. Turning towards the peninsular, Khari is again met in the Central Provinces, and, passing further into the tropics, we come across the comparatively thick and tall Hullu Kabu of Bellary and Ganda Cheni of Mysore—the latter appearing to be the southermost representative.

Now all of the forms of this group appear to be more or less liable to smut, a disease which is strongly inherited, by some at any rate of the P.O.J. descendants of Chunnee. For this reason, and because of the bad habit of its members the group was early rejected at Coimbatore for breeding purposes, and it is now never used for direct crosses in Java. The main fault of its various descendants is this liability to disease, which constant dilution of the Chunnee blood has failed to eradicate, and this liability is not confined to smut. Another disease has now come to the front in all sugar-cane countries, namely mosaic; and this at the moment plays a dominant part in the selection of seedlings. The Chunnee seedlings behave in a peculiar manner to this disease, in that they take it very readily but appear to suffer little from it. This is serious, in that they can pass on the disease, even when appearing to be quite healthy. They are in fact dangerous carriers of mosaic. The selection of Chunnee in the first instance in Java was thus unfortunate. In spite of the elaborate precautions taken before allowing it to enter the country, its true character was not grasped, for it is probable that it was just the kind of cane which they were trying to avoid introducing.

An entirely different project was undertaken when it was decided in India to attempt the improvement of the north Indian canes. Many of these were known to be extremely hardy, and, in spite of very primitive methods of cultivation, were generally free from disease. Smut was known, and also red rot, but the control of these was not difficult. The tonnage was, however, very low, and although some had good juice there was little of it as most of the varieties were very hard and fibrous. A Cane Breeding Station was opened at Coimbatore in south India, where the canes were known to flower very freely, whereas this was rare in north India, and a whole time botanist, who had had some experience in sugar-cane work, was placed in charge.

As will be seen, the disease aspect of the problem was not of the immediate importance that it was in Java, so full scope was allowed for cane improvement. But all previous efforts at raising cane seedlings in India had failed, and it was rather in faith that the Station received its name. This was however quickly settled, and abundant seedlings were soon being raised, at first among the local tropical canes, and, when they had been collected and brought together, among many of the north Indian canes. It will be noted that, in both cases, crosses were aimed at between rich tropical canes and poorer varieties in Java with the idea of imparting vigour and resistance to disease in the offspring, and in India with the idea of raising the richness and quantity of the juice. The bold expedient of reaching both of these objectives at the same time was tried at Coimbatore, by crossing tropical canes direct with wild grasses.

The main results at Coimbatore may be summarized as follows:—

(1) It was proved that abundant fertile seed was being produced by tropical canes in south India, and, on bringing down the indigenous canes from the north, all stages were met with between fertile seed and the total absence of flowering.

(2) The flowering indigenous canes were successfully crossed with various tropical canes, and both of these with at least two wild Saccharums, and multitudes of hybrid seedlings were raised.

(3) The conditions influencing the arrowing of the cane were studied, and it was very successfully controlled. Some of those from north India, which at first refused to flower, did so after some years, and produced seedlings, while others still remain without arrows or with distorted and useless flowers.

(4) The technique of raising seedlings has been greatly developed at Coimbatore, and is constantly being further improved; and this is now nowhere better understood.

(5) Seedlings have been produced which, after extensive trials in the north, are rapidly replacing the indigenous canes in certain localities. The canes are healthier than the old kinds and the yields are very much greater.

(6) A study of these northern canes was commenced at once and attempts were made at arranging them in groups. This involved a thorough overhauling of the minute points of difference in cultivated plants which were vegetatively reproduced, and a much greater knowledge of the morphology of the cane plant has been obtained.

Both in India and in Java, a main plank was the crossing of good tropical canes with hardy ones of a very inferior character; but the objectives were entirely different. Java, relying on the fact that resistance to disease is often strongly inherited, was content to accept the inevitable lowering of the quality of the juice, if freedom from disease could be assured. India, on the other hand, safeguarded on the disease question, could neglect the fall in quality of the juice of the tropical parent, because it was not intended to grow a high class of cane. One can fairly accurately calculate the juice quality in such cases, for experience has shown that the average along the seedlings in any cross is about the same as the average of the parents. Some of the seedlings would be above this and some below, so that there was a fair certainty that there would be a number with higher sucrose content than the indigenous varieties it was sought to replace.

But the problem for India was not altogether so simple as might appear from these facts. The Indian sugar-cane tract, covering some 1,000 miles north and south, and also east and west, has very different sets of conditions, in which also very different sets of indigenous canes have established themselves. Thus the task set split itself up into a considerable number of differing problems to be solved, one for each separate tract. One way to meet this difficulty would be to attempt to produce a number of seedlings which, in the field, would give, say, 20 tons of cane with juice of a fair quality and from these to allow the various tracts to select those which suited them best. This method has, as a matter of fact, been utilized to a considerable extent; but as knowledge increased, more and more attention has been paid to the needs of different places, and parents have been chosen specially to meet them.

Java's problem was of course different. Once a promising seedling had been obtained with good resistance and fair quality, it was necessary to raise this quality by successive stages until it could compete with the standard canes, and this meant a gradual dilution of the resistant character until it became evident that it was not safe to go further. This process is locally termed "ennobling" as applied to the inferior kind first crossed. The first step upwards is the actual first cross, the next would be crossing this hybrid with the same or another tropical cane variety of good character, the resulting seedlings being termed "twice ennobled" and so on. Of course the greater inherent resistance the tropical canes possessed, the further this ennobling could proceed and third or even fourth ennobling has been reached.

The unsuspected weakness of Chunnee proved to be ineradicable, and it was found impossible to proceed with this cane beyond a certain point, so that, in the end, it was finally discarded. Attention had meantime been drawn to a very hardy wild cane of unknown origin, called Kassoer, strong-growing and very resistant, but with very low quality of juice. After an exhaustive study of the character of this cane and of *Saccharum spontaneum*, called locally Glagah, the idea was formed that it was really a natural cross between the latter and a tropical cane. Later studies, including actual attempts at the reconstruction of Kassoer artificially and cytological examination, support this idea sufficiently strongly for it to be assumed that here a cane was ready to hand for use in breeding work, in the form of a once ennobled Glagah, and it slipped naturally into the place of the discredited Chunnee. With the experience gained, however, the process of ennobling was more rapid and it is satisfactory to learn that it did not exhibit the weakness of Chunnee, although in the fourth ennobling there were signs that the limit might have been reached.

The above sketch does not, of course, in any way cover the crossing programme being carried on at Pasoeroean in Java, nor indeed in the much smaller and more recent Station at Coimbatore. My aim was rather to make a comparative study of the difference in aims in the two places where seedling work is most energetically carried on at present. Every country will have its own problems to solve. The old system of introducing wholesale the seedling canes produced elsewhere has recently received a very rude shock because of the proof that many serious diseases have been introduced in this way. This may be considered to be a passing phase, if the quarantine arrangements turn out to be effective, and some of the smaller countries may prefer to resume the introduction of canes raised elsewhere. But every place where the industry is of any importance should have, and probably has, its own seedling section, or proposes to have one in the near future.

Enough has probably been written to indicate the lines of work which the writer considers should be carried out in all such cases where seedlings are being raised on the spot. The collection of all records and their publication in brief tabular form, so that the various steps in progress, as well as the failures, may guide the work of others; the formulation, year by year, of definite programmes of work, for benefiting the local canes grown, account being taken of the special conditions prevailing in the country; and the careful study of the technique evolved in

other countries, its adaptation to the local climate, and attempts to improve it, even in the smallest particular.

The raising of cane seedlings has been carried out in different parts of the British Empire for many years and many fine varieties of cane have been added to the tropical cane fields. Rightly or wrongly, the use of hardy but inferior canes of the Indian type has played no part in this work as it has in India and Java for special reasons. The writer feels that it would somewhat savour of impertinence to make suggestions as to the lines of research which should be undertaken in these countries, and the question, as to whether the costly and wearisome task of imparting resistance to disease by the methods described in the foregoing should be undertaken, must be decided locally in each case. In Barbados, Mauritius, Demerara, Trinidad, Jamaica, and latterly in Queensland and Natal, seedling work has been undertaken. In all these places there are scientific men on the spot fully capable of judging what line of work should be laid down, and of carrying it out. There is, however, a considerable accumulation of literature as to the local work, much of old date and difficult to trace, and I may be excused for expressing the opinion that it would be of great benefit, both to the country itself and to the different members of the British Empire, if this work could be collected and summarized, and made available for general information in some handy form.

In conclusion, of the many ideas which have suggested themselves in writing this paper, some remarks are added as to three of them. The first of these concerns tropical Africa, at present the chief centre of Colonial interest as regards the development of agricultural research. There is no doubt whatever that the people are fond of sugar and the sugar-cane. Why is it not grown? Well, of course, it is, and it would be interesting to dot out on the map the places where, in nooks and corners travellers have found it. But as to a sugar industry, there is practically none. Possibly there may be some in Angola, and the Transvaal has till recently obtained much of its sugar from estates in Mozambique. In the last few years also some marked progress has been made in Kenya and Uganda. Africa is a dry country, and, as such, ill-suited to the growth of crops needing much water; but so is India, and yet there are three million acres under sugar-cane, and some eighty million under rice. Africa cannot emulate this, of course, but it is a tenable hypothesis that, if the people of India had settled in the country generations ago, large areas would now be under both crops, whether by draining the swamps where the great rivers wind through hard land, or leading off channels for irrigation elsewhere. There are, of course, many factors to be considered besides water, stress of population for instance; but there are kinds of cane suited to almost all conditions where any agriculture can be developed, and I like to dream of the time when every village has its sugar-cane patch, with its primitive manufacture of raw sugar which, when added to the daily ration of the people, would make them stronger and more able to resist the onslaughts of many of the diseases which, unfortunately, are so characteristic of the tropical parts of this great continent.

The second point is of a very different character, and concerns the general policy of the raising of cane seedlings. There is a marked tendency everywhere to specialize on the production of seedlings adapted to purely local conditions. In the old days, a few kinds of cane were grown over the large parts of the tropics and gave magnificent results: nowadays, many of the important kinds grown in one country have proved useless elsewhere. To elaborate the possible reasons for this would fill the pages of a good-sized thesis. It is the boast of Java that they have such a wealth of seedlings that they can, after very little study, pick out one to suit any part of the country, nay, almost each field on each estate. The tendency is the same in India, and forms an important study in Hawaii, while Easterby has given illuminating details as to the distribution of cane varieties over the great stretch of the Queensland cane tract. Where are the seedlings, which, like Bourbon or Cheribon, and latterly like Badila, are capable of giving good returns over wide areas in different countries? The "general utility" cane has apparently gone out; and it seems to the writer that very strenuous efforts are called for its rehabilitation.

The last point concerns technique, namely, the increasing value of the recent developments in Cytology. This, it seems to the writer, should be added to the equipment of the botanist engaged in preparing accurate descriptions of all kinds of seedlings which are being taken up to any considerable extent on the plantations. That such descriptions are needed is now acknowledged on all hands if the regrettable mistakes of former years are not to be repeated. It is a special study of some difficulty, and would have to be undertaken at a well-equipped centre such as the recently founded Imperial College of Tropical Agriculture in Trinidad. The worst of it is that, for reasons which need not be entered into here, the sugar-cane, according to recent researches in Java, is a peculiarly difficult crop to deal with, but Cytology appears to possess a sort of "master key," with which it is hoped many of the mysteries surrounding the classification of the various discordant types of sugar-cane bid fair, once and for all, to be unravelled.

Students observing field operation on the Estates of the Ste. Madeleine Sugar Co., Ltd.,— Baling trash for convenience in handling.

Harvesting and Weighing cane on the experimental plots of the College.

AGRONOMIC RESEARCH IN THE SUGAR INDUSTRY.

BY

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IT is proposed in this article to discuss briefly some of the more important lines of work on the agronomic side of the sugar industry, those connected with the field aspects of production —varieties, soil management, crop practice.

In British sugar-producing countries the field side of research in sugar has received very inadequate attention, except for the variety question. This has been confined very largely to the raising and testing of new varieties by the usual methods with little or no attention to soil questions *per se*, the variety being made so to speak to fit the soil and conditions, the reverse aspect receiving practically no consideration. This was natural, being in the first place the quickest and in some cases the only possible line of approach. Moreover, the value of such results was easier to demonstrate, but the whole problem of variety deterioration, as it is often called, in which soil conditions are involved is still awaiting solution. Good canes come and go in rapid succession with frequently no explanation as to the actual cause. Superiority is claimed for the new varieties; this superiority does not always sufficiently take into account crop averages, climatic data, acreage considerations, improvements in equipment, &c. Furthermore, this superiority is as a rule relatively short-lived compared with the long and almost ubiquitous service of canes such as Bourbon, Cheribon, and other traditional varieties. Improvements from the point of view of sucrose per acre are natural to expect although even here increases are likely to come more slowly as the maximum for various conditions is approached. The time is probably not far distant, however, when it will be imperative to prolong the service of superior varieties which make their appearance only to be succeeded in turn by others more suitable to the medium in which their predecessors left off. From a psychological point of view these constant changes are perplexing to the grower who yearns for more stable varieties of the old type, of greater usefulness generally. The problem has received some attention, notably in Hawaii where root studies on Lahaina (Bourbon) have been undertaken. Factors associated with it may quite possibly respond to genetic analysis, but in any case the problem calls for a combined attack on the part of the agronomist, geneticist, and pathologist. It is one of considerable magnitude and can only be successfully undertaken in an institution with adequate facilities for a fundamental study of all the factors involved.

In respect to the technique of raising cane seedlings by the present methods, admittedly there is considerable room for improvement in the handling and testing with a view to more efficient elimination in early stages; initial work in Porto Rico on this phase is very commendable, but the correlation of characters on an extensive scale must be undertaken before such methods can be perfected. The problem is intimately associated with the descriptive and botanical aspects which have been receiving close study in Java and India. Indeed, the work in both these countries with which the names of Kobus and Barber will long be remembered is outstanding, and should be of great inspiration at the present juncture.

Dealing with the practical performance of varieties on a large scale, the writer has in a previous article (*vide Tropical Agriculture*, Vol. II. p. 73) referred to this as follows:—

"On the strictly commercial value of a variety, there is room also for considerable economic research. So far, little has been done in this direction. It is difficult for the experiment station, often with limited land facilities, to attempt, and co-operation with the grower would be necessary; I refer to the possibility of determining how varieties compare from the standpoint of sugar production costs. At the present time, varieties are judged largely on the sucrose yield per acre. With high-priced sugar nothing further need be considered; with low priced sugar, the necessity of figuring costs very closely becomes imperative. Obviously, cost accounting studies would have to be made and an accurate, comparative account kept at every stage—in field and factory; for it is clear that some varieties can be more cheaply grown agriculturally than others, while some are more economically handled in the factory, and *vice versa*. It is a question of reconciling the two so that the best financial results may be obtained."

It is true that problems of this nature must be finally solved in the individual countries themselves, but the Imperial College in Trinidad may be expected to take a lead in evolving methods of procedure which may serve as a general guide. Co-operation between field and factory must be

closely established, and the College Sugar Factory offers exceptional facilities for the collection of preliminary date.

Other considerations related to varieties which offer a wide field for further intensive work are : germination and tillering, growth and development (both root and stem), flowering and maturity, improvement by bud selection. A start has been made at the College in the agricultural section with the first two, while material for a comprehensive variety collection is being gradually brought together for further reference and study (*vide Tropical Agriculture*, Vol. II, p. 122, Vol. III, p. 154, Vol. IV in press).

Dealing next with soil management, it is realised that in the first place the physicist and the chemist will be expected to play a very important rôle in helping to simplify many of the difficulties met with ; on the other hand, tropical cane lands more often present problems which can only be solved in the final stages by the agricultural engineer and the agronomist, if permanency is to be assured. To those engaged in crop production in the tropics at the present time, it is becoming more and more essential to recognize the fact that plants need other things besides food, and such factors as soil aeration, soil moisture control, drainage, tilth, acidity and alkalinity are demanding greater attention than ever on the part of field men. Indeed, these considerations have long passed the stage when they can with safety be regarded as only of interest to the laboratory worker.

The success of the work on tillage, the measurement of resistance to implements, and other fundamental soil problems in progress at Rothamsted should be useful in indicating similar lines of field research under tropical conditions. In calling attention to this work in a short article (*vide Tropical Agriculture*, Vol. III, p. 4) the writer concluded as follows :—

" Let it be clearly emphasised, however, that in the tropics for a full measure of success to be achieved, the outlook in research must be broadened. The microscope and the test tube are no longer sufficient for our needs ; whatever else may be necessary, field conditions are such that the agricultural engineer with the plough, the tractor, the dynamometer and other mechanisms must be given facilities to add to his quota the sum total of our knowledge in the business in which we are engaged—that of raising crops and striving to do so profitably against heavy odds." Research of this kind will in the long run bring us nearer and nearer the goal of being able to measure, in precise terms, the value of an operation such as tillage, in the same way, let us say, as the chemist measures manure values or the physiologist moisture values.

Intimately associated with the soil problems referred to is the organic matter relationship to economic crop production. Under ordinary conditions, it appears to be paramount that this phase of soil management be not neglected, yet in many places large crops of cane continue to be produced with little attention to its conservation. The obvious question is how long can cane-growing be carried on profitably without in some way providing for maintenance of organic matter supplies—a consideration which we have been taught to recognise as the backbone of good farming. The collection of a large amount of data on this all-important subject now appears to be absolutely essential. In recent years, considerable progress has been made in the development of pen-manure substitutes, having for their object the reduction of costs in connection with manufacture and handling of pen-manure. Much careful study will be necessary to perfect methods in this sphere of activity before tropical requirements can be satisfied. Similarly, the green manure question is still incompletely answered in all aspects. While certain general facts have emerged from studies already undertaken in many countries, notably in India, much specific information is still lacking in regard to their rôle in crop nutrition. The results at Woburn, for example, where wheat and barley have followed tares and apparently not benefited from the nitrogen left by the tare crop suggest a wide field of enquiry for tropical researchers. So far as sugar-cane is concerned opinions differ markedly as regards the general usefulness of legumes ; some strongly advocate their use, others condemn it. Undoubtedly, much depends on economic conditions particularly in respect to labour and general crop practice ; nevertheless, tropical agriculture is far behind that of temperate regions in the development and employment of these useful plants. Here again a systematic collection and tabulation in some central place of data embracing experience and results in cane-growing countries with the growth and disposal of leguminous crops would aid very substantially in clearing up many points and difficulties.

There remains for brief treatment matters relating to crop practice such as methods of production, distance of planting, general treatment of growing crops, including manurial requirements and methods of application, ratooning, rotations, economic control of pests and disease.

Many of these are influenced in a very large degree by local conditions in individual countries, but such considerations as distance of planting and manurial requirements—to mention two—lend themselves to close fundamental study. It may be found on analysis that these can be determined to some extent by factors or relationships present in plant or soil. Any indication of such would be extremely valuable in practice, as indeed the preliminary work on response to manures in Hawaii has shown. So far as crop rotation in the truest sense is concerned, save in a few small centres in British territory and of course in Java where labour and estate conditions are not typical of the majority of cane-growing regions, little hope can be entertained that such practice will be ultimately adopted as a general policy. The difficulty lies in the finding of a crop or crops which will yield a cash return and can be easily handled and disposed of by the existing machinery of management. At any rate, indications are

College Experimental Plots.—Sweet potatoes, tobacco (seed selection plot) and bananas.

Sunn Hemp. A valuable soil improving crop.

that in many cane-growing regions at the present time interest is not wholly lacking in this subject as a result of the constant dangers from mono-cultural cropping. If even it were possible to utilize a cover or green crop after the last crop of ratoons is reaped, some gain, if only as a weed control measure, would be effected thereby. Practices of this kind, however, demand careful organization in the matter of seed supplies, which in the tropics has hitherto received scant attention. The agricultural section of the College has already started a study of cover and subsidiary crops for cane (*vide Tropical Agriculture*, Vol. IV, pp. 6 and 26). What is urgently necessary is for all the scattered information on this important subject to be collected and classified by a central authority. It is of course recognised that much can be done in many of these field problems by the close co-operation of the economist and agriculturist, for in the final issue it is the cost of production that determines what operations are profitable and what are not, what cropping practices are efficient and what are not. Such enquiries need to be regularised and firmly established as a definite part of any research programme undertaken for the industry as a whole. With a substantial land area attached, the Imperial College would be adequately equipped to give a lead to Empire producers in this very vital aspect of cane-growing.

In conclusion, the writer hopes that a complete sugar research station will before very long be created, where workers like himself responsible for the direction of sugar activities in different parts of the Empire may look for assistance and inspiration in the solution of fundamental problems, which can only be satisfactorily elucidated by ample provision for continuity and prolonged effort such as would obtain in an institution devoted exclusively to their study.

THE EXPERIMENTAL AND INSTRUCTIONAL CANE SUGAR FACTORY OF THE IMPERIAL COLLEGE OF TROPICAL ACRICULTURE.

BY

W. SCOTT, B.SC.,
Professor of Sugar Technology.

I. History.

IN the early discussions bearing on the establishment of an Agricultural College in the West Indies, the question of adequate instruction in Sugar Technology occupied a prominent place. The advocates of a Sugar school, foremost among whom were Sir Francis Watts, K.C.M.G., and Mr. Geo. Moody-Stuart, held that a small factory operated in conjunction therewith, was essential to the success of the scheme for at least two reasons :—

1. To provide the students, in one central location, with the necessary experience in different processes of Sugar manufacture.
2. To test new processes of manufacture and carry on experimental research on a scale which, though small, would be of practical value.

At the request of the Governors, Mr. Claude T. Berthon, A.M.I.C.E., interested himself in the project. At a meeting held at the Royal Technical College, Glasgow, on 14th June, 1921, and attended by representatives of firms interested in the production of sugar, and other related machinery, Sir Francis Watts and Mr. Berthon outlined the objects aimed at by the establishment of the factory. As a result of this appeal, principal items of equipment for the factory were promised by the various firms, the aggregate value of those gifts being estimated at fully £20,000.

The negotiations for the presentation of machinery, and the purchase of such parts as were not given, were undertaken by Mr. C. T. Berthon who devoted much time and thought to the scheme. He was solely responsible for the design of the factory, and the arrangement of the machinery, and acted in an honorary capacity as Consulting Engineer until his death on 29th July, 1925.

Owing to lack of immediate funds for the provision of buildings and other machinery to supplement the apparatus presented, work on the erection of the factory was only undertaken in 1924, and was completed in February, 1925.

The factory was officially opened by the Governor of Trinidad on 28th February, 1925, in the presence of several members of the Governing body and a large gathering of the Sugar Community of Trinidad. During the crop period of 1925, 2,606 tons of cane were crushed yielding 246 tons of sugar. Owing to lack of staff and apparatus no research work was undertaken ; the factory being operated for instructional purposes and on a semi-commercial scale.

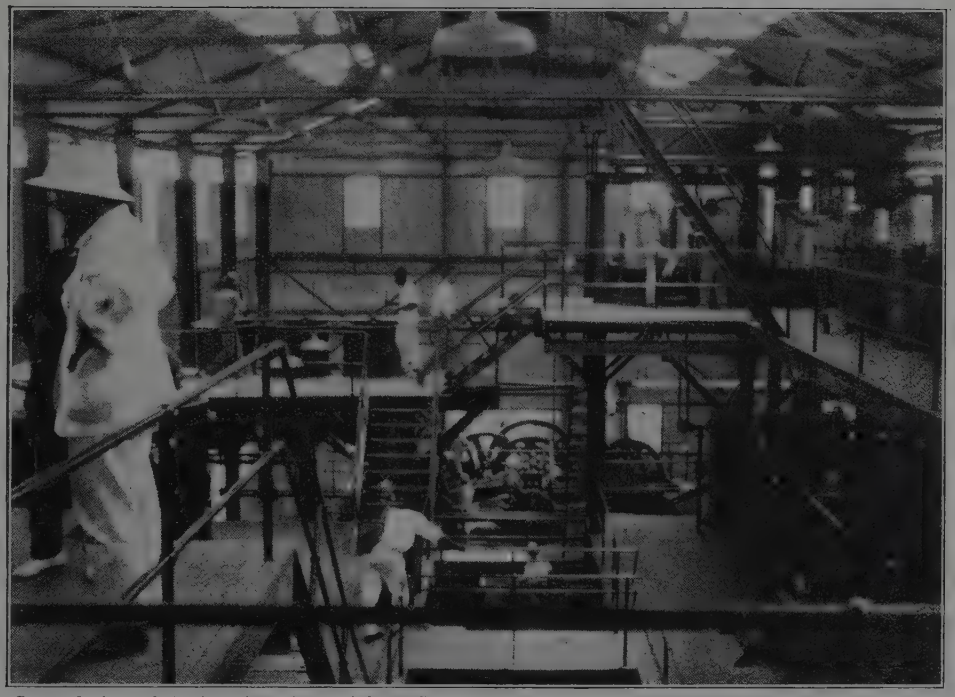
Following the resignation of Prof. Boyd at the end of the 1925 session, arrangements were made to continue the Sugar Technology courses, but the College Authorities realizing that no useful research could be undertaken in the factory during 1926, owing to lack of staff, funds and apparatus, accepted the offer of the Ste. Madeleine Sugar Co., Ltd., to provide for the practical training of the students in their factory. The students were therefore accommodated at Ste. Madeleine for the crop period where, besides receiving a thorough practical course in the factory, they began work on various problems on research, which work has since been continued if the College laboratories and factory. During this period plans were drawn for the re-organization of the Sugar Technology Department, special attention being given to research requirements. More apparatus was ordered, and a special research laboratory was provided for sugar work.

It was also decided to appoint an assistant Technologist to act as whole-time instructor, and a Research chemist, with special training in Bio-chemistry, to work in conjunction with the Departments of Chemistry and Technology on sugar problems.

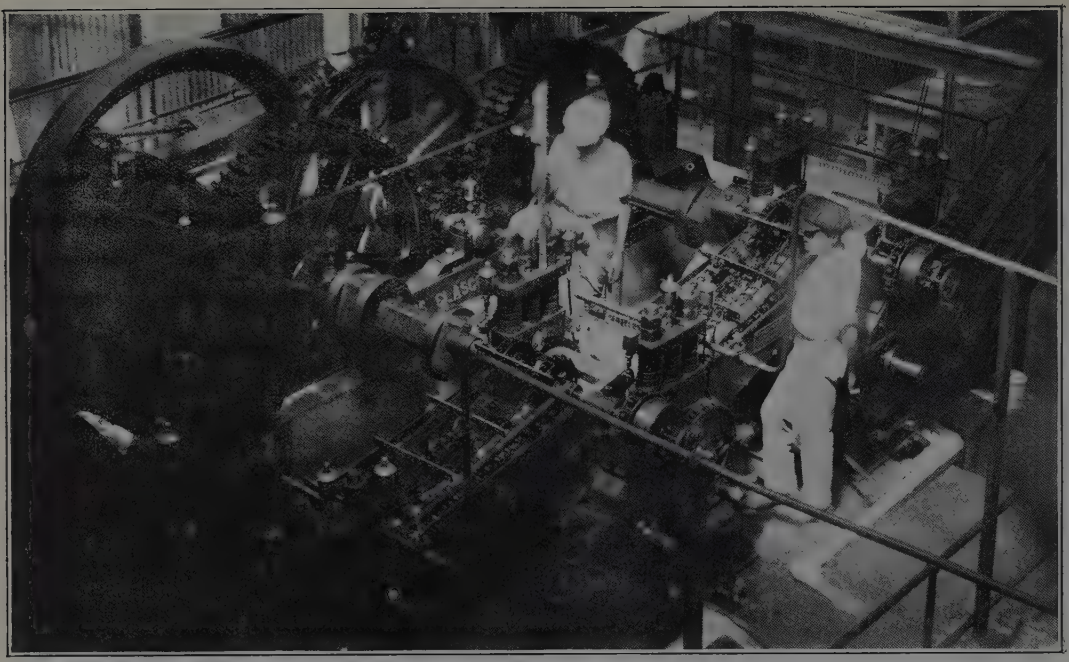
The 1927 crop, which included a carefully prepared programme of instruction and research, was recently brought to a successful conclusion, with the co-operation of the College Departments of Agriculture and Chemistry.

II—The College Sugar Factory Equipment.

Buildings. The main building is 112 feet 6 inches long, 40 feet wide and 29 feet high to eaves level, with a lean-to 15 feet wide. It is built of steel covered with corrugated sheeting, ample provision being made for lighting and ventilation. The boiler and economiser house, 72 feet long by 20 feet wide, is placed parallel to the factory building on its leeward side. Owing to financial considerations this latter building had to be constructed of timber covered with galvanized corrugated sheets.



General view of the interior of the College Sugar Factory, looking from the Pan Loft to the Mill.



College Sugar Factory.—The Eleven-roller Mill.

College Sugar Factory.— Juice Sulphiters, Eliminators, Filter Presses and Sulphuring Tower (in back ground).

A light shed of timber and galvanized sheeting partly protects the Cane Carrier and the labour employed in loading it.

Steam Generating Plant. Owing to the intermittent nature of the work the boiler power provided is somewhat in excess of proportions usual in commercial factories.

The Babcock & Wilcox boiler is of the W.I.F. type with a heating surface of 1,827 square feet, and designed for a working pressure of 160 lb. per square inch. The green megass furnace is of the step-grate type, with a total grate-area of 19.2 square feet. Forced draft can be supplied, when desired, by means of a 12-inch "Typhoon" turbine blower.

Supplementary firing with crude oil is provided by the pressure-atomizing system of the Babcock & Wilcox Co. The boiler is fed by a Weir land-type 4-inch pump and the feed water heated in a Green Economizer of the standard type consisting of 64 tubes 9 feet long, divided in four groups of 16 each.

By means of a by-pass flue and dampers, the economizer can be cut out at will, and the waste gases sent direct to the chimney. The latter is of steel lined throughout with brickwork, 100 feet high by 3 feet 6 inches net inside diameter, and of the self-supporting type.

Power and Lighting Plant. The power room contains two generating sets, one steam driven, and the other driven by an internal combustion engine.

The steam-driven set consists of a twin-cylinder high-speed, forced lubrication engine by Belliss & Morcom which, running at 525 R.P.M., develops 90 brake horse-power. This engine is direct connected to a level compound-wound direct-current generator capable of developing an output of 60 Kilo-Watts at 230-Volts. The generator was supplied by the Lancashire Dynamo and Motor Co.

The internal combustion set consists of a single-cylinder 12 H.P. Petters Crude oil-engine working on the two-stroke cycle direct connected to a 7 K.W. Level compounded 230-Volt G.E. generator. This set is used principally for driving the crystallizers and supplying lighting when the mills are not grinding.

The generators are controlled, and the current distributed, from a two-panel switchboard fitted with circuit breaker, ammeter, volt-meter, main switches and fuses, also shunt regulator for each generator, and distributing switches and fuses for outgoing circuits.

There are altogether twelve electric motors in the factory driving pumps, centrifugals, crystallizers and other accessories.

The factory is lighted by high-power, gas-filled lamps in Mazdalux dispersive reflectors carried on tie rods of the roof trusses, while smaller lamps in similar reflectors are used for lighting individual stations.

Milling Plant. The complete plant, presented by the Mirrlees Watson Co., consists of a Krajewski crusher followed by a nine-roller mill, all rollers being 21 inches long by 16 inches in diameter. The nominal capacity of the plant is 2 tons of cane per hour; in practice nearly 3 tons can be readily ground per hour with close settings.

The pressure is applied to the top rollers by heavy spiral springs capable of imposing a load on each roller of from 30 to 40 tons, depending upon the initial compression of the springs. Cane and megass rollers can be adjusted by means of set screws held in the side cap; while the trash turners are adjusted by means of lever and tension screws.

The engine driving the mills is of the single cylinder horizontal slide valve type, 12-inch diameter by 20-inch stroke, with the spur-gearing arranged to give roller surface speeds of from 17 to 20 feet per minute in the various mills when the engine is running at 90 R.P.M. Link motion reversing gear is provided so that all mill rollers may be reversed when necessary.

The intermediate megass conveyors are driven from the top rollers of the second and third mills respectively. Those conveyors consist of steel troughs along the bottom of which the megass is dragged by steel paddles.

Provision is made for macerating with last mill juice and with water.

The megass is carried from the last mill by an elevator to a chamber above the megass furnace, in which a Denison scale is provided to weigh the megass, when this is considered desirable.

Clarification Station. The plant is arranged in such a way that any desired sequence of liming, sulphuring and heating can be followed. By this arrangement various processes of Clarification can be demonstrated, and research work is made possible without extensive changes in the connections. The juices from each mill can be collected in separate tanks, pumped to corresponding tanks near the roof, and weighed in three 50-gallon tipping-bucket weighing machines. Under normal working conditions, the juices from the crusher, first and second mills are mixed, the third mill juice being used for macerating. Only the mixed juice and maceration water are usually weighed.

The Clarification plant proper consists of: Three cylindrical liming tanks 3 feet diameter by 6 feet deep provided with conical bottoms. Two sulphitors 2 feet 6 inches diameter by 7 feet deep with conical bottoms and stirring gear driven by a 1½ h.p. motor. Sulphur Stove of 1 square foot burning area, with gas scrubber and cooler; dried air is supplied to the stove by a Westinghouse air compressor.

The Sulphitation equipment is supplemented by a Demerara type cascade sulphur box, 2 feet square by 11 feet high.

Two juice heaters, one of which is of the high velocity type with 60 tubes and 60 passes exposing 100 square feet of heating surface, while the other of the low velocity type, has 60 tubes with 4 passes and a heating surface of 134 square feet. The pipe

connexions are so arranged that the juice can be passed through either heater alone or through the two in series. Both heaters are fitted with high and low-pressure steam supply.

A separator 2 feet by 2 feet by 3 feet 6 inches deep, fitted with baffle-plates frees the hot juice from the heaters from vapour. From this separator the juice flows by gravity into a battery of six first subsiders 4 feet by 3 feet by 3 feet provided with ball-float decanting pipes and mud and washout plugs.

Two self-cleaning type eliminators allow the clear juice from the subsiders to be boiled and skimmed on their way to the evaporators. The juice can also be sent direct from the first subsiders to the evaporator supply tanks.

Scum and Filter-press Station. Three second subsiders, of a size similar to the first subsiders, receive the bottoms from the latter. The clear juice from those subsiders can be delivered into the eliminators or the evaporator supply tanks at will. The mud is prepared for the filter-presses in a pair of scum-boiling tanks each 4 feet by 3 feet by 2 feet 6 inches. The scum-boiling tanks, as well as the second subsiders, are provided with perforated steam coils.

The filter-press equipment consists of three Johnson presses—two for juice and one for syrup—of the plate and frame pattern, each press having 18 chambers with plates 19 inches square and a filtering area of 81 square feet.

A Johnson clarifying filter, similar in design and construction to those of Philippe & Danek, with a total filtering area of 385 square feet is provided for the final filtration of juice or syrup. This filter is fed under a head of 10 feet from a tank located on the first subsider floor fitted with copper coil and steam trap for heating the juice or syrup before filtration.

The filter-press pump is made entirely of bronze with three independent barrels and is capable of delivering against pressure up to 100 lb. per square inch. One of the plungers is used in pumping mud, another for forcing syrup through the filter-press while the third is used for pumping the clear filtered syrup to the vacuum pan supply tanks.

This pump arrangement is illustrative of the scheme followed throughout the factory. Electrically driven three-throw pumps with cylinders independent from each other are used, each cylinder performing a separate function.

Evaporation. The Harvey Triple Effet Evaporator, is of the standard vertical type, with vessels 3 feet 4½ inches in diameter, and a total heating surface of 700 square feet. The design of the vapour pipes provides wide openings for the entrance of vapour to each calandria, and special arrangements are made to ensure the removal of air and incondensible gases lodging in any part of the calandrias. The condensate from the 1st calandria is removed by means of a trap. For the removal of condensate from Nos. 2 and 3 calandrias alternative appliances are provided: (1) a pair of vertical double-acting Nichols pumps, (2) a pair of 1½-inch automatic vacuum traps. The discharge of pumps, or traps, is delivered to two small tanks on the working platform so that the water can be collected and weighed when evaporation tests are being made.

A surface condenser having 312 square feet of cooling surface is provided instead of a barometric condenser, in order that the amount of entrainment might be observed and the weight of water evaporated accurately determined. Condensate is extracted from the condenser by a 1½ inch auto-discharger which operates in a similar manner to the vacuum traps of calandrias.

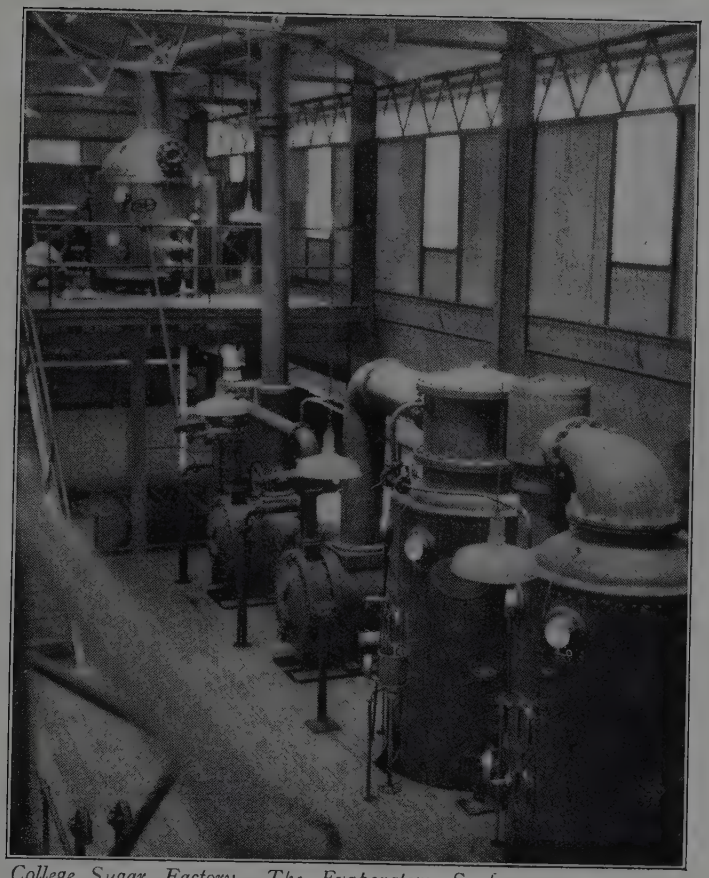
The vacuum for both evaporator and pan is maintained by a horizontal steam-driven dry slide valve air pump with steam cylinder 7 inches diameter, air cylinder 11 inches diameter, both cylinders having a 9-inch stroke. The jacket and covers of the air cylinder are water-cooled. An alternative means of producing vacuum is by means of a multijector air exhauster, operating on the ejector principle and utilizing high-pressure steam jets.

The cooling water is obtained from wells, but owing to insufficient supply the water is kept in circulation by an electrically-driven centrifugal pump and cooled by means of a spray-cooling system.

Crystallisation and Curing. Syrup from the evaporator is pumped to a tank placed at a sufficient height to allow of weighing in an Avery tipping-bucket weighing machine ; or else, to four tanks provided with closed copper coils. From those tanks the syrup can gravitate to the pressure tank of the clarifying filter, or to the Syrup Sulphitor. The latter is similar in design to the juice sulphitors but is provided, in addition, with a closed copper coil and steam-trap. The stirring-gear of the sulphitor is driven by a 1½ h.p. B.T.H. motor through Croft reducing gear. From the sulphitor the syrup passes to a receiving tank on the ground floor from which it is pumped, through a pressure vessel to the syrup filter press. The clear syrup is received in another tank on the ground floor and returned to the vacuum pan supply tanks.

The vacuum pan is 4 feet 6 inches diameter by 4 feet 2 inches deep in belt, with three solid-drawn copper coils with a total heating surface of 86 square feet. Its normal strike capacity is 55 cubic feet. High or low pressure steam can be supplied to each coil from vertical manifolds at the side of the pan. A cast iron fitting interposed between the bottom flange of the pan and the discharge valve carries two 4-inch pipes and valves. By means of one of those pipes a footing of Massecuite can be drawn back into the pan from one of the crystallizers ; the other pipe allows of dry seed sugar being introduced into the pan from the operating platform.

A surface condenser similar in design to the evaporator condenser, but with a cooling surface of 227 square feet is provided for the pan. A sluice valve placed on the cooling-water exit of the condenser, and a valve on the air pipe leading to the vacuum pump, allow the pan boiler to regulate the temperature and vacuum in the pan to suit requirements.



College Sugar Factory.—The Evaporators, Surface Condensers and the Vacuum Pan.

The pan discharges into a gutter placed on top of three crystallizers located on a stage directly below the pan; the massecuite can be admitted either to the crystallizers or direct into the mixer.

The crystallizers are of the U-shape, open-top type with jackets provided with steam and water inlet and outlet valves. They have a capacity of 60 cubic feet equal to a full strike of the pan. The centrifugal mixer will take a full charge of one crystallizer; and at one end there is an additional compartment fitted with a syrup liquoring pipe, reserved for the purpose of double-curing of sugar.

The centrifugal installation consists of two 24-inch "Weston" machines, driven by belting from friction pulleys at 1,500 r.p.m. The outer castings of the machines are fitted with inside and outside steaming apparatus, and hinged plate steaming covers. A double gutter at the back of the machines allows of separation of thick molasses from washings. The crystallizer and centrifugal installation is driven by a 15 h.p. B.T.H. motor through a counter-shaft. Final molasses is delivered to a 4,000-gallon storage tank outside the factory.

Refining. Simple refining operations are made possible by the provision of a Sugar melter 4 feet 6 inches by 3 feet deep. This is a self-contained unit with its own motor, centrifugal liquor pump, &c. The melt liquor is delivered into the Syrup Sulphitor, which can also be used as a mixing tank. After treatment by the Bach process, or with vegetable carbons, the liquor is filtered in the plate-and-frame press and sent to the vacuum pan supply tanks.

Piping. All juice, syrup and molasses piping in the factory is of copper. The live-steam and exhaust-steam pipes are protected by asbestos insulation.

General. It was the aim of the designer to make this factory a model of cleanliness and sanitation, and his object has been fully achieved. At the busiest period of operations, the factory always presents a neat and tidy appearance; there are no pits in the ground-floor to collect fermentable matter, while the lighting and ventilation leave nothing to be desired.

III. Contributions to the Factory.

The Sugar Factory owes its existence largely to the generous contributions of a number of well-known British Machinery firms, and to the unselfish labours of its designer Mr. Claude T. Berthon, A.M.I.C.E. The following is a list of the equipment presented, or supplied on very favourable terms, by the firms mentioned.

LIST OF EQUIPMENT PRESENTED TO THE COLLEGE EXPERIMENTAL FACTORY.

B. & W. Water Tube Boiler	*Babcock & Wilcox, Ltd.*
Boiler Mountings	*J. Hopkinson & Co., Ltd.*
Fuel Economizer	*E. Green & Son, Ltd.*
Boiler Feed Pump	*G. & J. Weir, Ltd.*
Milling Plant (11 roller), complete	*The Mirrlees Watson Co., Ltd.*
Mill Juice Tanks	*Millen Bros.*
Pump (three throw) for Juice	*Joseph Evans & Sons, Ltd.*
Juice Heaters (two)	*A. F. Craig & Co., Ltd.*
Eliminators (two)	*Fawcett Preston & Co., Ltd.*
Triple Effet Evaporator and Staging	*The Harvey Engineering Co., Ltd.*
Filter-Presses (three)	*S. H. Johnson & Co., Ltd.*
Gravity Filter	*S. H. Johnson & Co., Ltd.*
Filter-press Pump	*S. H. Johnson & Co., Ltd.*
Filter-press Tanks	*S. H. Johnson & Co., Ltd.*
Vacuum Pan and Staging	*A. & W. Smith & Co., Ltd.*
Condensers (Surface), Two	*George Fletcher & Co., Ltd.*
Vacuum Pump	*George Fletcher & Co., Ltd.*
Multijector Air Pump	*The Mirrlees Watson Co., Ltd.*
Crystallizers (three)	*Watson Laidlaw & Co., Ltd.*
Strike Mixer	*Watson Laidlaw & Co., Ltd.*
Centrifugals (two) and accessories	*Pott, Cassels & Williamson*
Sugar Melting Pan (complete unit)	*Duncan Stewart & Co., Ltd.*
Engine driving Main Dynamo	*Bellis & Morcom, Ltd.*
Electric Motors (eleven)	*The British Thomson-Houston Co., Ltd*
Control Gear	*The British Thomson-Houston Co., Ltd*
Centrifugal Pump (for Condenser Water)	*Drysdale & Co., Ltd.*
Centrifugal Pump (for General Service Water)	*Worthington-Simpson, Ltd.*
Air Compressor	*Ste. Madeleine Sugar Co., Ltd.*
Oil Separator (two)	*Bakers (Leeds), Ltd.*
Auto-Dischargers (two) for Condensers	*Holden & Brooke, Ltd.*
Weighing Machine for Cane	*Henry Pooley & Sons, Ltd.*
Weighing Machine for megass	*S. Denison & Sons, Ltd.*
Weighing Machines for Liquids (three)	*W. & T. Avery, Ltd.*
Donation towards Equipment	*Donald Clerk & Son, Ltd.*
Reducing Valves (two)	*David Auld & Sons, Ltd.*
Reducing Valves (three)	*Sir W. H. Bailey & Co., Ltd.*
Valves	*Glenfield & Kennedy, Ltd.*
Copper Pipes	*Yorkshire Copper Works, Ltd.*
Do.	*Allen Everitt & Sons, Ltd.*
Do.	*Broughton Copper Co., Ltd.*
Exhaust Steam Piping	*Stewarts & Lloyds, Ltd.*
Miscellaneous Cast Iron Piping	*Shaw Glasgow, Ltd.*
Miscellaneous Wrought Iron Piping	*Norman Pearson & Co., Ltd.*
Bolts and Nuts	*D. Willetts, Ltd. & J. M. Mitchell.*

EQUIPMENT SUPPLIED ON SPECIAL TERMS.

Factory Building	*A. & J. Main & Co., Ltd.*
"Typhoon" Turbine Blower	*Murray Mc Vinnie & Co., Ltd.*
Chimney	*Westwood & Wrights.*
Reducing Gear for Economizer Scrapers	*Northern Manufacturing Co., Ltd.*
Liming Tanks	*Westwood & Wrights.*
Juice Sulphitors (two)	*Sugar Machinery Manufacturing Co., Ltd.*
Syrup Sulphitor	
Sulphur Stove	
Gear for Sulphitors	*Croft, Ltd.*
Calandria Pumps	*Nichols Pump & Eng. I. Co., Ltd.*
Automatic Vacuum Traps	*Royle's Ltd.*
Generator—60 K.W.	*Lancashire Dynamo & Motor Co., Ltd.*
Generator—7 K.W.	*General Electric Co., Ltd.*
Internal Combustion Engine	*Petters, Ltd.*
Switchboard	*Whipp & Bourne, Ltd.*

The following contributions towards the operation of the factory during the 1927 crop have been received :

Total Lubrication Requirements of the Factory, for Crop 1927	*Presented by the Texas Co., through Messrs. Geo. F. Huggins & Co., Ltd. (Trinidad).*
Decolourizing Carbon, for Refining Experiments	*Presented by the British Suchar Process Corpn.*
Fuel Oil	*Supplied on Special terms by the United British Oilfields (Trinidad).*

In the compilation of this article, the writer has drawn freely from a series of articles in the *West India Committee Circular* (1925) by Mr. C. T. Berthon, A.M.I.C.E.

One of the Chemical Laboratories of the Department of Sugar Technology.

THE EXPERIMENTAL AND INSTRUCTIONAL CANE SUGAR FACTORY. CROP 1927.

A Summary of Operating and Experimental Results

BY

W. SCOTT, B.SC.
Professor of Sugar Technology.

A COMBINED programme of Instruction and Research in Sugar Manufacture had been outlined during the first term of the session by the Departments of Sugar Technology and Chemistry. This programme was successfully completed during the past crop.

The College Sugar factory was operated from the 14th of March to the 21st of May, grinding for ten hours daily, the cane supply being obtained from fields of the Cotton Research Station and from the College Experimental Plots. Owing to the unseasonable weather, the quality of the cane was poor. Various types of Sugar were manufactured, including Demerara Crystals, Refined White Crystals, Special Greys and Molasses Sugar.

The following figures are taken from the manufacturing Report for the crop :—

	per cent.
Sucrose in Cane	9.96
Fibre in Cane	13.61
Sucrose in megass	4.48
Fibre in megass	43.91
Moisture in megass	49.94
Normal Juice, Brix	15.17
Sucrose	11.83
Apparent Purity ..	78.02
Glucose Ratio ..	15.42
Final Molasses :	
Apparent Purity	33.34
Cane Ground : Tons	1288.92
Do. do. per hour, Tons ..	2.89
Sugar made	93.56
Tons Cane per Ton Sugar	13.77
Sucrose in Juice per cent.	
Sucrose in Cane	86.07
Sucrose in Sugars per cent.	
Sucrose in Cane	69.81
Sucrose in Sugars per cent.	
Sucrose in Juice	81.11
Fuel Oil Consumed, Tons	55.11

The recovery figures cannot be compared with corresponding figures from commercial factories on account of the very intermittent nature of operations of the College factory, and also owing to the fact that refining losses are included. Besides, mistakes influencing recovery figures are purposely allowed to be made.

The principal features of the instructional part of the work were as follows : For several weeks previous to grinding the students were assigned for a definite number of hours weekly to the factory, where, under supervision, they took part in the overhaul and assembly of the machinery ; thus familiarizing themselves with the construction of the various parts of the factory equipment. During this period preliminary analyses on laboratory samples of juices and syrups were made in order to adjust methods and develop team work in the determination of phosphates, silicates, pectin, pentosan, total colloids, &c. This was in preparation for the research work on factory samples.

During the crop the students divided their time between the factory and the laboratory. Their laboratory duties included analytical work bearing on both chemical control and research. In the factory, the practical features of factory control and operation were emphasized, and the 4th year students were given a certain amount of responsibility in supervising operations. They were also given every opportunity of taking a direct part in the operation of various stations, particularly in the handling of the vacuum pan.

Milling. A " typhoon " cutter was lent by the Ste. Madeleine Sugar Co. for experiments in the preparation of cane. Owing to the type of carrier and crusher being unsuitable for the extreme fineness to which the cane was cut, the experiments in this direction had to be abandoned. Another series of experiments was, however, outlined and carried out with a motor-driven 10-inch and 12-inch laboratory mill at Ste. Madeleine, in order to determine to what extent preliminary preparation of cane could help small factories with a three or six-roller mill. The results obtained were rather interesting.

TABLE I.
Cane Variety B.H.10(12).

Preparation of Cane.	ANALYSIS. Cane % Suc.	JUICE. Brix.	JUICE. Suc.	JUICE. Purity.	N. Juice. Extraction % Cane.	Sucrose Extraction.
I. Whole Cane	17.28	22.3	20.63	92.51	72.38	86.41
II. Cut in 3-inch lengths ..	16.89	22.1	20.46	92.58	69.51	84.18
III. Cut ¾-inch or less ..	17.21	22.2	20.50	92.34	63.01	75.06

The cane in each case was crushed three times, *i.e.*: until no further juice could be extracted by dry crushing. The results show that without efficient surface drainage, pressure regulation and maceration, an actual drop in extraction is experienced with more efficient preparation of cane owing to re-absorption of juice and greater resiliency of the finely divided cane.

At the factory proper the settings of the various mill rollers were closely watched and gradually altered by Mr. C. T. Watts, the Factory Engineer. After the third run, a specially grooved feed roller was installed on No. 3 Mill, and after the fifth run, No. 2 Mill was provided with a similarly grooved feed roller. Each change involved a further alteration of settings. The results of the various alterations up to 30th April follow :—

TABLE II.

Run No.	ANALYSIS. Cane % Suc.	MEGASS. % Suc.	MEGASS. % Fibre.	MEGASS. % Moisture.	Remarks.
I.	9.23	5.94	39.14	52.50	
II.	10.81	5.68	40.28	52.20	
III.	10.63	5.43	40.29	52.03	
IV.	10.17	3.30	46.47	48.93	Third Mill feed roller grooved and settings changed.
V.	10.40	3.29	48.01	47.40	
VI.	10.01	3.10	47.61	47.90	Second Mill feed roller grooved and setting changed.

We were glad to welcome Mr. Wyllie, Consulting Sugar Engineer, who devoted a whole day of his short stay in Trinidad to the College, delivered a lecture on " Modern Milling Practice " and gave valuable advice on the setting and operation of the mills.

Variety Experiments. The yield of cane from each of the College Experimental plots was ground separately, the results recorded being as follows :—

TABLE III.

Variety.	CANE. % Sucrose.	CANE. % Fibre.	CRUSHER JUICE. Brix.	CRUSHER JUICE. Sucrose.	CRUSHER JUICE. Purity.
SC.12/4	11.70	11.52	17.03	14.64	85.96
B.H.10(12)	10.98	9.84	15.77	12.62	82.50
Ba.11569	10.94	10.68	15.90	12.94	81.67
B. 156	9.71	10.32	14.80	11.55	78.04
Crystallina	9.67	9.42	14.50	11.40	78.62
Ba. 6032	9.45	11.50	14.00	11.12	79.43

The order in which those varieties occur in the Table follows closely their usual classification in Trinidad. SC.12/4, however, usually comes second to BH.10(12).

Loss in weight of cane by evaporation. The reaping of the experimental plots did not proceed fast enough to keep the mills supplied. The reaping of a plot was therefore begun in the morning, each cart being weighed on arrival at the factory, and unloaded in close proximity to the carrier. The grinding would begin about 1 p.m. when most of the cane from the plot had arrived. Part of the cane had then been on the yard from three to four hours. It was found impossible to balance exactly the weight of megass and juice against the weight of cane. (No maceration water was applied during the grinding of the experimental plot canes in order to reduce possible variations in sampling.) This fact prompted the following experiments on loss by evaporation between the time the cane is weighed and the time it is ground.

(1) A cartload of cane weighing 2,162 lb. arrived at the factory at 9.30 a.m. It was unloaded on the yard in the usual way ; then reloaded and weighed at 1.45 p.m. The cane then weighed 2,084 lb. showing a loss in weight of 78 lb. or 3·67%.

(2) Another cartload weighing 1,819 lb. was left on the yard from 8 a.m. to 12 noon ; and was found to have lost 38 lb. or 2·08%.

The average loss of weight in four hours combining the results of both experiments was 2·91%.

Those experiments illustrate the difficulty of obtaining reliable control figures when many hours elapse between the weighing and the grinding of the cane received at a factory. The loss in weight is affected by so many factors that no constant allowance can be made. The logical conclusion is that cane should be weighed immediately before being placed in the carrier. This would mean providing in some cases several scales instead of one.

Effect of cane-tops on the recovery. Further experiments were made to determine the detrimental effect of cane-tops on the sugar recovery. Another object of those experiments was to attempt to define a limit for the topping of cane. Interesting results were obtained with the laboratory mill ; but owing to the immature state of the cane during this crop the results are not considered representative of normal conditions, and will be combined with results obtained next year.

Research on elimination of certain non-sugars during clarification and concentration. The object of this investigation was to estimate the percentage of certain non-sugars removed during clarification and concentration, by determining the quantities of such substances present in the different factory products. The products investigated were : mixed juice, clarified juice and syrup. It was not found possible to extend the investigation to include final molasses. The non-sugars forming the subject of the investigation were : phosphates, silicates, pectin, pentosan, total colloids and nitrogenous substances. The chemical determinations were made by Messrs. Springer and Davies, fourth year Students ; while the physical measurements were obtained by Dr. Hurst. Valuable help was received from Prof. Hardy and the Department of Chemistry.

The entire run covered a sampling period of ten days, six of which were devoted to the best possible clarification by lime and heat, one each to overliming and underliming, and two to defecation aided by the addition of calcium superphosphate at the liming tanks.

A paper by Messrs. Springer and Davies giving analytical procedures employed, references, and tabulated results will be published later. In the meantime their conclusions will be of interest here.

They found from the results of determinations on mixed juice that the percentages of the substances investigated show considerable variation, the proportion present depending presumably on the degree of ripeness of the cane and the extraction of the mills.

With reference to the elimination of the non-sugars under consideration they mention the following points :—

(1) Pectin, phosphate, silicate and colloidal matter are most completely eliminated by overliming, whilst the smallest percentages removed appear in the underlimed and phosphate series.

(2) The appearance of the clarified juice and syrup of the phosphate series was exceptionally good, those products showing no sign of turbidity, being of perfect clarity, brilliancy and colour.

(3) Very appreciable quantities of most components are precipitated when the juice is concentrated to syrup, especially in the phosphate series.

(4) Pentosan is removed in similar proportions throughout the five series, which is an indication that this removal is due to the efficient heating practised in the College factory. An almost constant temperature of 215° F. was maintained, but it is uncertain whether the disappearance of pentosan was due to hydrolysis to pentose sugar, or to dehydration and consequent precipitation in the mud. The large percentages of pentosan removed on concentration in the phosphate series are noteworthy, but the actual cause of this disappearance needs further investigation.

(5) Nitrogenous substances are removed in larger quantities in both the overlimed and underlimed series than in normal defecation. In underlimed juice those impurities are heated in solution of a pH value near their iso-electric point and therefore tend to be largely precipitated.

The physical measurements on the composite samples of the series described above included the determination of brix by Zeiss' Refractometer ;

electrical conductivity by Kolrausch's method; surface tension by Traube's Stalagmometer, and viscosity relative to water at the same temperature by Ostwald's Viscometer. In the determination of H-ion concentration, the quinhydrone electrode gave excellent results; and it was found possible to use it with alkaline solutions and sulphited syrup (latter not included in research series) if measurements were made rapidly and the first reading taken as the correct one.

The determination of physical measurements have given useful suggestions for detailed investigations in various directions. Probably the most important results concerning sugar manufacture were obtained in the series involving addition of phosphoric acid to the raw juice. The phosphate content of the juice throughout the crop was low; and it was not possible with ordinary liming to obtain a really brilliant juice. The additions of phosphoric acid not only produced a very clear and brilliant clarified juice, but the surface tension measurements in this series on both clarified juice and syrup indicated an effective removal of tension-lowering impurities.

Continuous pH recording. A tungsten Mn_2O_3 continuous pH recorder was fitted up in the factory to the clarified juice discharge pipe by Dr. Hurst. He experienced trouble with the tungsten electrodes, and found it necessary to standardize each one (after standing in the juice for some time) by comparison with the readings of the quinhydrone electrode. The apparatus was then very sensitive to slight changes in pH.

Centrifugal clarification of syrup and molasses. This series of experiments on the centrifugal clarification of syrup and molasses was performed in the laboratory of the Ste. Madeleine Sugar Co. by Messrs. Davies and Springer, fourth year Students. The centrifugal used in those experiments was designed by Mr. J. Hamill of the Honolulu Iron Works Co., and made by the S.S. Hepworth Co. of New York for the Ste. Madeleine Sugar Co. The bowl of this machine is 6½ inches internal diameter by 5 inches diameter of overflow and gives a separating effect of 800 times gravity at 3,350 R.P.M. It is driven by a ¼ H.P. D.C. Motor running at 1,750 R.P.M.

The average combined results of the syrup series were as follows :—

Average weight of material treated	13280 gms.
Do. do. washed and dried residue	8.25 gms.
Do. do. residue per cent. weight of Syrup	0.063
Speed of Bowl	3300 R.P.M.
Temperature of Feed	85°-90° C.

Analytical Results.

	Before Treatment.	*After Treatment.*
Brix	63.20	62.80
Sucrose (Pol.)	50.24	50.78
Apparent Purity	79.50	80.86
Sucrose (Clerget)	50.94	51.44
Gravity Purity	80.60	81.91

The average combined results for the molasses series were :—

Average weight of material treated	8376 gms.
Do. do. washed and dried residue	10.75 gms.
Do. do. residue per cent. weight of Molasses	0.127
Speed of Bowl	3300 R.P.M.
Temperature of Feed	85°-90° C.

Analytical Results.

	Before Treatment.	*After Treatment.*
Brix	78.29	78.18
Sucrose	36.11	37.26
Apparent Purity	46.12	47.66
Sucrose (Clerget)	40.20	41.90
Gravity Purity	51.35	53.59

The average increase in gravity purity in the syrup series was 1·31 and in the molasses series 2·24. It will be noticed that the increase in purity in both cases is more largely due to an increase in sucrose than to a drop in the Brix. It must however be taken into account that a certain amount of evaporation takes place during the treatment as the syrup and the molasses are both heated to about 90° C. in order to reduce the viscosity.

Relative viscosity determinations were made, using an ordinary burette as viscometer. A slight drop in viscosity was noted in every treated sample.

The residue from the syrup samples contained 67·5% organic matter, and the residue from the molasses 53·5%. The principal inorganic constituents of the syrup residue were silicates, phosphates, lime, iron and alumina. The inorganic constituents of the molasses residue were

principally silicates, sulphates, lime, iron and alumina. The presence of sulphates in the molasses residue arises from the fact that the molasses was produced from sulphited syrups, while the raw syrup treated had not been sulphited.

Clarification of syrup and molasses affords an interesting field for investigation ; and centrifugal treatment seems to offer the best chances of success.

Sugar Refining. Approximately 6½ tons of sugar were washed to 98·5 Purity and used in demonstrating two different processes of refining. Half the melt liquor was treated by the Bach Sulphitation method, and the other half was treated with Suchar.

The Suchar liquor was lighter in colour and a better grade sugar was obtained therefrom. Both grades of sugar were, however, considered to be of excellent quality.

In the determination of surface tension and specific conductivity on treated filtered liquors it was noted that the surface tension of the Suchar liquor was higher, and its specific conductivity lower than the corresponding measurements on the Bach liquor. Those facts would indicate the presence of less colloidal matter and salts in the Suchar treated liquor.

The refining operations occupied three days during which 4.58 tons of white sugar were produced.

General output. The principal grades of sugar manufactured consisted of Demerara Crystals, Special Grey crystals for direct consumption and Molasses Sugar. Those sugars were well thought of locally, and were readily absorbed by the local market.

Conclusion. The value of the work done during the past season is greatly enhanced by the fact that it has brought to light various problems, the solution of which would be of great benefit to the industry. Those problems will be investigated during the coming year ; and we hope to be able to report satisfactory progress in a not too distant future. In recording the close of a successful crop, special tribute should be paid to the untiring efforts of Mr. D. M. McAllister, M.A., Assistant Technologist, who was in charge of factory operations ; of Mr. C. T. Watts, Engineer, and of the College Department of Agriculture which voluntarily assumed responsibility for the cane-supply, and supervised the reaping and transport operations.

SOME APPLICATIONS OF PHYSICO-CHEMICAL DETERMINATIONS TO THE CONTROL OF SUGAR MANUFACTURE

BY

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IT IS generally recognised that the processes of sugar manufacture are profoundly influenced by physical conditions and that improvements in procedure will most profitably be made in the light of our knowledge of such conditions. It is proposed in this article to discuss shortly the significance and value of measurements of surface-tension and electrical conductivity.

SURFACE-TENSION.

The writer's conception of surface-tension may be stated in very brief outline as follows:— The molecular forces acting across an interface between two phases, say water and air, or water and a solid, are different from those acting across a plane drawn through the bulk-interior of either of the two phases. There is thus an unbalanced force at the interface and for equilibrium to be reached, the molecules of both phases at the interface and up to very small distances from it adopt different spacings from those in the interior of either phase and are thereby in a strained condition. The combined effects of these molecular strains constitute what is known as the interfacial or surface tension. When a foreign particle comes into the vicinity of the interface, it is, if its presence lowers the surface-tension, impelled towards the interface and tends to be retained there, *i.e.*: it is adsorbed; if its presence increases the surface-tension it tends to migrate from the interface.

The tension-lowering impurities (chiefly colloidal material) present in sugar juices, syrups and molasses are concentrated in surface layers and cause interference in every operation in sugar manufacture. Measurements of surface-tension give a rough quantitative estimation of the amounts of such colloids and so furnish a very simple means of controlling the efficiency of processes which aim at their removal. These processes are concerned in the main with adding to the liquid, or causing to be formed within the liquid itself, insoluble particles at the surface of which the interfering colloids are adsorbed. Clarification processes also take advantage of the fact that colloids carry an electric charge and that when this is neutralised, *i.e.*: at the iso-electric point, coagulation of the colloid takes place. In the simple defecation process this has been regarded purely as a matter of hydrogen-ion concentration, but the writer holds that the loss of these electric charges is only indirectly responsible for the coagulation of suspended colloids and that for the most part this phenomenon is due to the changes occasioned in the surface-tension at the colloid-water interface.

In the interpretation of the results of surface-tension measurements the following points should be considered:—

1. Where several adsorbable substances are present together in solution (as in all sugar-house solutions), the one which is capable of producing the greatest lowering of surface-tension will tend to be adsorbed preferentially and to exclude the others. It follows from this that surface-tension measurements can only be regarded as giving a rough measure of the total amount of colloidal matter in solution and might in some cases give very erroneous results. It is probable, however, that a careful interpretation of surface-tension measurements would give a truer indication than total colloid content of the difficulties that might be expected in various factory processes.

2. The surface-tension that is measured experimentally is that of the free surface of the solution (*i.e.*, the liquid-air interface). In a study of crystallisation the interfacial tension concerned is that between the sugar crystal and the solution, and this is impossible of measurement. Care should therefore be taken in making inferences of the effects of colloids on crystallisation purely from surface-tension measurements.

3. During boiling and crystallisation, surface-viscosity is of great importance and might be much larger than that in the interior as measured by the viscometer. Here again, however, the depression of surface-tension is not necessarily a measure of the surface-viscosity, for the less tension-lowering materials would tend to be excluded from the surface independent of their viscosity.

It is clear that there is a large field of research available for the study of cane and beet colloids from the point of view of surface-tension measurements; and the relations existing between surface-tension, viscosity, and hydrogen-ion concentration might have to be exhaustively studied for real progress to be made.

Electrical Conductivity.

The specific electrical conductivity of a solution depends on the following factors :—

1. The nature of the ions (both positive and negative) present in solution and the relative amounts of each. Every ion makes its individual and characteristic contribution to the total conductivity and this varies considerably for different ions.

2. The viscosity of the solution. Conductivity depends on the mobility of the ions and the mobility is inversely proportional to the viscosity of the environment. Thus in a viscous sugar solution the ions will have a very much lower mobility than in pure water solution.

3. Concentration of the electrolytes in solution. Conductivity is concerned only with ions and the more dilute a solution is, the greater is the extent of the dissociation into ions of the dissolved molecules.

4. Temperature. Conductivity rises rapidly with temperature and a correction should be made for any temperature change or, preferably, measurements should be made at constant temperature.

A great deal of work has recently been done in an attempt to correlate the ash content of sugar-house solutions with their specific electrical conductivity. The ash content of a sample (as determined by incineration) depends almost entirely on the weight of metallic radicles present, and is independent of solubility, dissociation, viscosity, and the presence of acid radicles which are burnt off during the incineration. It seems clear, therefore, that the electrical method of estimating ash is only applicable to products whose ash contents are approximately similar in nature and amount, and that when this is not so, very inaccurate results could be obtained.

For this reason the method would not be likely to give consistently reliable results with cane juices, particularly since many cane varieties of differing ash content are utilised. With raw or refined sugars from the same general sources these objections are not usually met with and the method has been applied successfully in many such cases once the relation between conductivity and ash has been established for the particular type of sugar under examination. Variation in viscosity is prevented by using a sugar solution of definite concentration. If conductivity is plotted against viscosity for varying concentrations of a sugar solution, a curve is obtained which exhibits a maximum conductivity at a concentration of between 30 and 40% solids. It is therefore preferable for experiments to choose a concentration of sugar in the vicinity of this maximum point since slight variations in viscosity, and therefore in concentration, will have practically no effect on the conductivity reading and the experimental errors will thus be minimised.

For accurate chemical control, however, the determination of the ash content of sugar solutions and products, without further knowledge, is insufficient for the obvious reasons already indicated that it gives no real information of the relative amounts of the metallic or acid radicles that are present. In this connection it is possible that with further research conductivity measurements might be employed to greater advantage than they can be at present.

On the theoretical side much use may be made of conductivity measurements and a problem which this department will investigate concerns the nature and mechanism of formation of molasses. By a study of the ionisation of salts in various environments, along with the construction of phase-rule diagrams, it is hoped to throw further light on this subject.

BY-PRODUCTS OF THE SUGAR INDUSTRY.

BY

W. Scott, B.Sc.
Professor of Sugar Technology.

The casual visitor to a Modern Sugar Factory is generally greatly impressed by the various devices for securing maximum steam economy; by the use of megass for fuel, of filter cake as fertilizer and of molasses for various purposes, and leaves with the impression that "nothing is wasted."

The technologist, however, cannot share the enthusiasm of his guest in this respect; as the mere fact of *utilizing* a by-product does not preclude the idea of *waste*. He is not satisfied, that, in certain cases, those products are being used to the best advantage, especially when he takes into account their potential value in other directions.

The position in which the different by-products of the sugar industry stand at the present time is briefly reviewed below as well as some of the difficulties which lie in the way of utilizing them in a more profitable manner.

Cane Trash—Tops.

The value of this by-product of the Cane field is still a debatable question. In such progressive sugar-growing areas as Java and the Hawaiian Islands the trash is burnt. In Cuba it is left in the fields where it provides a mulch which is very effective in preserving moisture and keeping down weeds. In Mauritius and the British West Indies the trash is generally taken to the cattle pens where it is used as bedding, and later returned to the fields as pen-manure. On one progressive estate in Trinidad cane-trash is actually baled in the fields, then transported and stored in close proximity to the cattle pens for use as bedding throughout the wet season. All trash and other materials for bedding is passed through a chaff cutter before being placed in the cattle pens.

Recent experiments on irrigated areas in Hawaii disclosed no benefit from the burying of trash; Deerr on the other hand states that a marked improvement followed the burying of trash on estates where no irrigation was applied.

Undoubtedly the varying practice in different sugar countries is dictated in each case by economic, climatic and soil conditions. It seems, however, that where conditions are favourable, the safest and most scientific way of dealing with cane trash is to return it to the soil in the form of pen-manure.

Megass or Bagasse.

Since the discovery in the early days of the cane-sugar industry that sun-dried megass could supply at least part of the fuel necessary to operate the factory, many efforts have been directed towards making the sugar factory self-supporting from the fuel standpoint. Those efforts have been so successful that many modern factories at the present time have a large surplus of megass over their fuel requirements.

Until quite recently little could be done to utilize this surplus profitably. In Hawaii a coarse paper has been manufactured which is used as a mulch on pine-apple plantations. In other countries the surplus has been utilized in locomotives or for off-season power requirements, although in Java it is held that megass and cane leaves are not very suitable fuels for locomotives on account of their slow rate of combustion. Where no more profitable use could be found for the surplus megass it has been simply returned to the fields, or sent to the cattle pens.

Recent developments give promise that megass may in the near future become an important source of cellulose for various industries. The possibility of using other fuel for operating the cane-sugar factory, thereby releasing the megass, is already being considered in various quarters; and actually practised in Louisiana.

Fibre Board:—The best known megass product of this class is "Celotex" manufactured in New Orleans, La. It is claimed to possess remarkable heat and sound insulation properties; and is extensively used for such, and other purposes. New plants for the manufacture of this product are to be erected in Porto Rico and in Australia.

Other projects are being developed for the manufacture of light boards from megass which will be used largely for packing cases and as substitutes for lumber generally.

Paper Pulp;—According to Deerr attention was first called to the possibilities of megass as a paper-making material in Guadeloupe in 1872. Dry megass (fibre) contains over 50% cellulose.

Various projects have been launched from time to time to produce paper from megass; but attempts at manufacturing grades of paper above the coarsest types were not successful commercially. One of the principal difficulties

in the production of high-grade pulp from megass arose from the formation of coloured substances during the digestion of the crude megass. The bleaching of the resulting pulp then became a difficult and costly operation.

The Nanji process, recently patented, claims to have overcome those difficulties by the adoption of a new principle for the digestion of the pulp from the crude megass. The time required for digestion is considerably shortened, and the yield of dry pulp amounts to about 40% of the weight of the air-dry megass. The pulp produced by this process, judging from a sample received, is of high quality.

There is but little doubt that a successful process for the manufacture of high grade paper pulp from megass offers great commercial possibilities owing to the diminishing supply and increased cost of transportation of pulp wood.

Other Industries :—Cellulose produced from megass has been used in various industries within the past two years, principally in the manufacture of explosives and of artificial silk.

The sugar manufacturer in the Tropics who desires to dispose of his megass in the most profitable manner is faced with several problems which require careful consideration :—

1. Assuming that there is a market for megass, the disposal of surplus megass might be profitable whereas the substitution of other fuel for megass might result in a loss. The profitable substitution of other fuel for megass will depend on various factors : the relative net market value of the megass and of the new fuel, the thermal efficiency of the boiler plant and boiling-house ; facilities for economical handling of the new fuel, &c. The margin of profit if the megass is to be disposed of as a raw material, would be a narrow one ; and the matter should be carefully considered before undertaking costly alterations in the boiler plant.
2. Megass is a light material and must be baled for export. The best practical result so far obtained in baling megass containing 47-48% moisture is a compression to about 35-40 lb. per cubic foot. After a month's storage the baled megass weighs about 20-25 lb. per cubic foot. Even with favourable rates, the cost of freight is extremely high when compared with the value of the material.
3. The most desirable solution, from the sugar manufacturer's viewpoint, would be to undertake the manufacture of a finished or semi-finished article at the factory. In the case of fibre-board, and such articles, the problem of distribution would have to be faced ; but as regards paper pulp, the bleached product could be sold in bulk to paper manufacturers.

Interesting and revolutionary changes in the equipment of cane-sugar factories would probably follow the general substitution of other fuels for megass. It is not improbable that the supremacy of the Milling process would be once more challenged by advocates of the Diffusion process. The use of independent continuous diffusion units might provide the flexible capacity considered desirable in cane-sugar factories ; while the difficult problem of elimination of colloids from the juice would be automatically solved by the adoption of the Diffusion process. Quintuple or sextuple effet evaporators, vapour heating, thermo-compressors and Calandria pans would also become familiar features of the Cane-Sugar factory equipment.

Molasses.

Fuel :—Molasses can be used to supplement megass for steam production. According to Deerr, one pound of molasses containing 60% total sugars and 20% water will afford on combustion 4,500 B.T.U. This is approximately the heat value of one pound of megass containing 40% moisture. Calculated on the basis of heat units and average value of other fuels, the market value of molasses, as fuel, would not exceed 1¼ cents per gallon.

The practice is not therefore to be recommended except in localities where fuel is very expensive and no profitable outlet for molasses exists.

Rum :—A rum distillery was, at one time, considered an important factor in the economic life of the tropical sugar industry. This condition still exists in a few sugar-producing districts ; but generally speaking, prohibition in some countries and high taxation in others, have contributed to reduce the production of rum for export to a very low figure.

Few hopes can be entertained for any considerable expansion of this industry in the future. Some distilleries which manufactured rum in the past, are now producing industrial alcohol.

Alcohol and by-products :—According to Arnstein : "the most profitable manner of utilizing molasses is in the production of Alcohol, Yeast, and their by-products." Dr. Arnstein's sweeping statement does not apply equally well in all sugar-producing countries. His figures refer chiefly to production in the United States and Germany. In those countries there is a very large, and still growing, demand for industrial alcohol which is used in many chemical industries. A similar demand exists, or rather has been created, for Yeast for baking purposes, human consumption or cattle fodder. The growth of the Yeast industry in the United States has been stimulated by advertising campaigns of astounding proportions.

Again, there is a greater demand in the United States for carbon dioxide than in any other country in the world. Carbon dioxide is used principally for carbonating beverages, food preservation and refrigeration.

A large proportion of the molasses from which some of those products are derived is imported into the United States from tropical cane-sugar-producing countries. The price obtained by the

sugar producer seldom averages three cents per gallon. He has therefore no share in the huge profits made by the big Alcohol and Yeast concerns of the United States. On the other hand the difficulties confronting the individual producer who attempts to develop his own by-product industries can be best illustrated by the following example :—

Some years ago the writer was requested to investigate the technical and economic aspects of utilizing molasses for the production of Alcohol, Yeast, CO_2, Potash, &c., in a British Colony. The results of the investigation were as follows :—

1. The Excise laws of the Colony made no provision for the manufacture, or sale, of industrial alcohol or motor spirit.
2. The production of fresh Yeast was out of the question owing to the necessity for constant refrigeration.

   Dried Yeast tablets could be produced, but no market was known to exist in England for this product.
3. The production of Carbon dioxide during fermentation is equivalent to 49% of the weight of sugars present. By using closed Vats in the distillery the Carbon dioxide could be recovered, purified and liquefied at very low cost.

   The value of Carbon dioxide was 8 cents per lb. or $4.00 per Cylinder. The Cylinders cost $15.00 each and weighed 100 lb. The annual consumption of Carbon dioxide in the Colony could have been satisfied by less than a day's output from the existing distillery. The cost and weight of the cylinders made the export of the Carbon dioxide to far distant countries unprofitable.
4. The recovery of fertilizer material from distillery slops in the United States distilleries visited, whether accomplished by the Porion kiln or by the Spray-drying system, was accompanied by a larger expenditure for fuel than the fertilizer was worth. The necessity for the installation arose from the fact that those plants were located near cities, and were compelled by law to destroy the refuse from their distilleries.

Some of the problems involved in the profitable production of industrial alcohol, or motor fuel, are not likely to be solved by the individual initiative of the sugar manufacturer. Much, however, could be accomplished by co-operative action in the development of markets, and the removal of legislative barriers.

Alcohol Motor Spirit :—It is not easy, nor is it intended here, to forecast when the increase in the use of internal combustion engines might cause an actual shortage of petrol. The real cause for concern is the fact that the British Empire produces only a very small proportion of its petrol requirements; and it is therefore of vital importance that a fuel intended to supplement and, if necessary, to replace petrol be developed. Alcohol has been chosen as the logical fuel for this purpose, partly owing to the fact that its sources of supply are of vegetable origin and therefore inexhaustible.

Owing to its higher density and lower volatility alcohol fuel might not be able to compete with high grade petrol in aircraft engines for some time to come. For other purposes, however, especially if used in suitably designed engines using a high degree of compression (180 lb. per square inch), the consumption of alcohol in gallons per horse power per hour compares favourably with the consumption of petrol in a petrol engine of the same size and speed. With the maximum degree of compression for alcohol, an alcohol engine can develop 30% more horse-power than a petrol engine of the same cylinder size, stroke and speed. Alcohol will operate almost any petrol engine with a well designed carburettor, the principal differences being : the ease of starting and the certainty of operation at low speeds.

The Alcohol Motor Fuel Industry is in its infancy; and, according to Freeland, many problems are still left for research to solve. Some of those problems are :—

(*a*) Reduction of costs, by more efficient methods of fermentation and distillation.
(*b*) Methods of producing absolute alcohol.
(*c*) Development of better fuel mixtures.
(*d*) Stabilization of Ether to prevent, or reduce, its evaporation and decomposition.
(*e*) Cheap, efficient and suitable denaturants.
(*f*) Adaptation of alcohol fuel to existing engines and development of new types of engines.
(*g*) Cause and prevention of corrosion.

Apart from Technical problems, there are others which are of equal importance and which must be solved if the industry is to be established on a firm foundation.

Among such problems might be mentioned the following:—

1. Standardization of the product to conform with very strict specifications.
2. A system of distribution which will be in a position to compete with the highly organized system for petrol distribution.
3. A more liberal and enlightened policy from the various Governments in favour of alcohol for industrial purposes.

Cattle food :—Cane Molasses (Blackstrap) are used to a considerable extent in the manufacture of cattle food in many countries. Molasses cattle food, using cane pith as an absorbent, was first produced on a large scale in Demerara under the name of "Molascuit" by Mr. G. Hughes. The manufacture of Molasses feeds has, however, gradually shifted from the producing to the consuming country. The deterioration of the product during shipment and storage was largely responsible for the change; careless methods of manufacture may have been largely to blame for the deterioration.

Pure Molasses feeds are deficient in nitrogen and must be supplemented with material rich in protein. Molasses feeds might provide a suitable

outlet for the utilization of rotation crops on sugar plantations. Part at least of the product could be consumed locally; while the balance could be exported if the problem of deterioration in transit is solved. The moisture in such products should not be allowed to exceed 10-12 %, and cleanliness in manufacture must be observed.

Fertilizer :—Molasses are used as fertilizer principally in Mauritius and Java. Blewett in the *S. A. Sugar Journal* states that the applications of Molasses to plant canes in Mauritius ranges from 4 tons to 15 tons per acre. On a cycle of one crop of plant cane and five ratoons the total increase of cane as the result of one application of molasses amounted to as much as 20 tons per acre. Assuming that this increase was produced by the application of 15 tons molasses per acre, and taking the cane as worth $3.00 per ton, we note that the molasses realized $2\frac{1}{3}$ cents per gallon. If the increase could be secured by smaller quantities of molasses, and the cane was worth more than $3.00 per ton, the value of the molasses employed in this manner would be correspondingly enhanced. The results following the application of molasses in Mauritius are greater than might be expected from their composition; and the explanation given is that the molasses aid the nitrogen-fixing organisms in their work, thereby increasing the nitrogen content of the soil. Manurial experiments with molasses in various other countries have not produced the results noted in Mauritius and Java.

Minor By-products.

Among the minor by-products of the industry we may class filter-press cake, ashes, and various refuse containing organic matter.

Filter-press cake :—The composition of filter-press cake varies somewhat according to the process of defecation employed. The quantity of press cake obtained per cent. of cane in ordinary defecation factories varies from 1.5 to 4.5, depending largely on: amount of lime used, variety of cane, cleanliness of cane, amount of cush-cush in the juice, &c. It contains as it comes from the presses from 60 to 70% moisture 0.25 to 0.3% N, and between 2 to 3% phosphate of lime; as well as a large amount of organic matter, some sand and clay, and some cane-wax. It is better appreciated as a fertilizer material in certain countries than in others. In heavy clay soils deficient in humus applications of filter-press cake have produced results which could not be explained by the chemical analysis of the material.

At Ste. Madeleine, in Trinidad, the filter-press cake is utilized in two ways. On certain estates it is used for "moulding" cattle pens in crop time. A layer of about six inches of press cake is evenly distributed over the pen, say once or twice a week. Litter is placed over this and the trampling of the cattle allowed to continue. According to G. A. Jones (Agronomist) the resulting pen manure is of excellent quality. Another portion of the filter-press cake produced from this factory is taken to a siding located at a short distance from the factory. The ashes from the furnaces are also taken to this siding; and throughout the crop a heap is built consisting of alternate layers of ashes and filter-press cake It is planned to add to this heap in the future all refuse containing organic matter, and to spray the heap at intervals with "lees" from the distillery.

Ashes :—The ashes collected from the furnaces are rich in potash and phosphates; and it seems that the most logical way of disposing of them is according to the method described above. When not applied as a fertilizer ashes on sugar plantations are used on railway tracks or pathways.

Light bricks for paving can be made from ashes by using a suitable press.

Conclusion.

This general review of the position of "By-products" will help, to a certain extent, to explain the so-called "apathy" of the sugar manufacturer in the tropics. The stagnation of the past few years has been largely due to lack of organisation and proper orientation in the Industry taken as a whole.

With the recent organization in London of a "Sugar Federation;" with the support of the Empire Marketing Board and the help of liberally supported Research Institutions, the Empire Sugar Industry enters a new era. There is therefore little fear that the development of By-products will be overlooked in a constructive programme designed to stabilize the Sugar Industry of the Empire.

THE COMPONENTS OF SUGAR-CANE JUICE.

Their Mode of Occurrence and Behaviour During Sugar Manufacture.

BY

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NORMAL mill-expressed sugar-cane juice may be regarded as a mixture of the following main substances or classes, in the approximate weight-proportions stated.

	Per cent. by weight.	*Per cent. Total solids.*	*Per cent. solids not sugar.*
Water	80-85		
Sucrose	10-18		
Hexose or "reducing" sugars ..	0.3-3.0	11.0-22.5	
Other organic compounds ..	0.5-1.0		
Inorganic compounds	0.2-0.5		0.7-1.5

The variations in content of these components are considerable, and depend on variety of cane, age, and conditions of growth, as well as on mode and degree of expression practised in the factory.

Assuming average figures, the components *other than sugars* (*i.e.*: "non-sugars") occur in the following entities and amounts.

Non-Sugars in average cane juice.		*Per cent. of Total Solids.*
(*A*) *Carbohydrates* (other than sugars)		
Hemicelluloses and Pentosans (chiefly xylan)	8.5	
Pectins ("cane-gums and pectins")	1.5	
		10.0
(*B*) *Organic Nitrogen Compounds.*		
Higher proteins, mainly of albumin type	7.0	
Simpler proteins (Albumoses and Peptones)	2.0	
Amino-acids (*e.g.*, glycine and aspartic acid)	9.5	
Acid amides (chiefly asparagine) ..	15.5	
		34.0
(*C*) *Organic acids* (excluding amino-acids)		
Various "fruit" acids and carbohydrate acids (Aconitic, oxalic, succinic, glycollic and malic)	13.0	
		13.0
(*D*) *Colouring matters.*		
(Chlorophyll, anthocyans, "saccharetin" and tannins) ..	17.0	
		17.0
(*E*) *Waxes, fats and soaps.*		
("Cane-wax")	17.0	
		17.0
(*F*) *Inorganic salts.*		
(Phosphates, chlorides, sulphates, silicates, nitrates of sodium, potassium, calcium, magnesium, aluminium and iron chiefly) ..	7.0	
		7.0
(*G*) *Silica.*		
(Free, or in organic combination) ..	2.0	
		2.0
Total	100.0	100.0

The striking features in these figures are (1) that more than one-third of the total solids-not-sugar are organic nitrogen compounds of protein type, (2) that waxes, fats and soaps occur in unexpectedly large proportion, and (3) that carbohydrates other than sugars (the so-called "gums and pectins") occur in relatively low weight-proportions, even though they present perhaps the greatest difficulty in their elimination during the customary process of cane-juice defecation.

Mode of occurrence of the components of cane-juice.

Certain of the solid components of factory sugar-cane juice (about 60 per cent.) occur in a state of true solution, others in a so-called "colloidal" state, and the remainder, in a state which may be described as intermediate between the soluble (crystalloidal) state and the colloidal state.

The chief truly-dissolved compounds include the sugars, the amino-acids and acid-amides, the various organic non-nitrogenous acids, and most of the salts. The main colloidal components are hemicelluloses, pentosans and pectins, the higher proteins, the waxes, fats and soaps, and free silica. Of doubtful position are anthocyan,

saccharetin and tannin pigments, certain of the less-soluble salts, and the simpler proteins (albumoses and peptones).

Generally, a certain amount of *suspended* filterable matter occurs in factory cane-juice even after thorough straining. This suspended matter includes minute chlorophyll granules, and the finest particles of megass (" bagacillo " or " cush-cush ") which may become a source of considerable factory trouble, because of their decomposability under the influence of various circumstances that arise during sugar manufacture. Canes reaped in wet weather, in addition, often convey finely-divided clay into factory juices. Finally, cane-juice contains gases (chiefly air and carbon-dioxide), which occur either in a state of solution or of suspension as tiny bubbles.

Behaviour of juice-components during factory processes.

The object of the cane-sugar manufacturer is to eliminate the non-sugar " impurities " from sugar-cane juice, with the least possible destruction of the valuable component, sucrose. The chief agents used in the factory are *heat* and *lime*. In addition, other chemical agents, such as phosphoric acid, sulphur-dioxide, carbon-dioxide, and various physical agents, such as diatomaceous earth and decolourizing chars are often employed.

The effects of Heat.

(*a*) *Detrimental.* Rise in temperature, apart from sterilizing the juice, accelerates most of the chemical changes that tend to occur therein, for cane-juice is an unstable mixture of mutable substances that interact one with another. Thus, the breakdown of sucrose into hexose sugars through the action of water (" hydrolysis "), and controlled by degree of natural acidity of the juice (pH 4.6 to 5.8), is greatly enhanced when cane-juice is heated. Furthermore, prolonged heating of sucrose in solution leads to caramelization with concomitant undesirable darkening in colour.

The oxidation hexose sugars into various volatile, or dark-coloured, or acidic substances, is also doubtless enhanced by heating, although other factors, such as alkalinity and the presence of phosphates and iron, are probably of greater moment. (*See* " Oxidation of Glucose," *Trop. Agric.* Aug., 1926, Vol. III, p. 165.)

Heating, besides accelerating the hydrolysis (" inversion ") of sucrose, also accelerates the hydrolysis of hemicelluloses and of the true-cellulosic components of bagacillo. This generates further quantities of gummy pentosans, and is therefore highly detrimental. One of the chief disadvantages of the modern use of hammer-shredders in the cane-mill lies in the fact that it produces large amounts of bagacillo, which, unless straining be very efficient, gain access to the factory juices.

(*b*) *Beneficial.* Colloidal substances such as hemicelluloses, pentosans, pectins, proteins and silica, are prone to dehydration, and therefore to a reduction in their degree of colloidality, by heating. This dehydrating effect may proceed far enough actually to cause their precipitation (in the case of albumin), or to facilitate their subsequent elimination by lime (in the case of silica and perhaps of pectins). It may at least render them somewhat more susceptible of removal by physical agents which act through surface combination (" adsorption "). In the case of organo-silica compounds, believed by some to occur in sugar-cane juice, heating may effect fission, so that the silica fraction is separated in a more or less hydrated state (*See* " Defecation of Sugar-cane juice," *Trop. Agric.*, Oct. 1925, Vol. II, p. 231).

Continued hydrolysis may effect some disruption of pentosans and pectins into pentose sugar and other simple non-colloidal residues, though little is yet known of the possible significance of this action, which may have far-reaching importance.

Finally, heating disengages much dissolved and suspended air from cane-juice, and this may carry upwards a scum of suspended solid matter in a way familiar to the early users of open eliminator pans.

The various effects of heat, both desirable and undesirable, are considerably enhanced when juice-heaters that cause super-heating (116°C) are employed.

The effects of Lime.

The addition of lime to cane-juice produces two different and distinct results. Firstly, it reduces acidity, and may instead impart alkalinity. Secondly, it adds calcium to the juice.

Neutralization of acidity, as is well known, prevents loss of sucrose through hydrolysis (" inversion "). Alkalinity, however, encourages the oxidation of hexose sugars, and increases the formation of dark-coloured "humic" substances resulting from this change, and from a similar change that may also affect the carbohydrate non-sugars, such as pentosans. Hence alkalinity is one of the main factors leading to excessive darkening in colour of cane-juice in the factory.

The addition of calcium produces profound results, calcium combines with proteins to form insoluble coagula which settle ; it forms insoluble compounds with some of the organic acids, and with many of the inorganic salts, notably phosphates ; it may yield a certain amount of insoluble calcium pectinate ; it produces insoluble calcium soaps from the fats and waxes, and it combines with and precipitates free silica and clay. Furthermore, some of these various lime-precipitates are said to carry down with them significant amounts of the less-amenable impurities, such as pectins, pentosans, proteins, and colouring matters. Belief in this last mentioned fact has

partly led to the deliberate addition of phosphoric acid or of soluble phosphates to cane-juices deficient in phosphate, in order to improve their defecation by liming, and to the practices of sulphitation and of carbonation in white-sugar manufacture (*See Trop. Agri.*, Jan., 1927, Vol. IV, p. 14), (phosphatation) and *ibid* April, 1926, Vol. III, p. 74 (sulphitation). In addition to generating an absorbent precipitate in limed cane-juices, sulphitation effects temporary lightening in colour, due to the well-known reducing action of sulphur-dioxide. This decolorization, however, is not permanent, and white sugars, whose manufacture has involved sulphitation, gradually darken on storing in contact with air.

Behaviour of certain special components.

1. *Fats, waxes and soaps.*—These substances may give great trouble in the cane-sugar factory, both because of the difficulty in effecting their precipitation, and because of their greasy nature, which renders limed cane-juice filtration slow and tedious. "Cane-wax" melts at about 82°C., and is therefore melted and floated off the cane-rind during milling when maceration with hot-water is practised, and during heating when wax-impregnated bagacillo is plentiful in the juice. Liming only partly precipitates fats, waxes and soaps, and cloudiness in limed and settled juices is frequently attributed to their presence. Furthermore, the calcium salts ("soaps") derived from them are a common cause of evaporator scale.

2. *Pentosans and Pectins.*—These highly hydrous colloidal substances escape complete precipitation by heat and lime, although they may be partly eliminated by adsorbents, such as diatomaceous earth, various chars, and surface-reactive precipitates, such as calcium phosphate, calcium sulphite and calcium carbonate that are generated in limed juices by various procedures. Ordinarily, most of the pentosans and much of the pectins, pass into the final molasses. Their presence in molasses somewhat inhibits crystallization, but apparently not so much as the so-called "melassigenic" inorganic salts, such as alkali-chlorides, to which are nowadays ascribed the chief power of preventing sucrose crystallization.

3. *Colouring matters.*—*Chlorophyll* is present in suspension especially in cane-juice from unripe canes. It is usually easily eliminated. *Anthocyan* pigments, which occur in significant amount only in the juices from red and purple-rinded canes, exhibit characteristic colour changes as the reaction of the juice is altered by liming. In acid juices, the colour is pink; in alkaline juices, it is dirty blue-green. Excess of lime appears to effect some precipitation of anthocyan pigments; adsorbent chars, even in acid media, completely remove them, but sulphur dioxide does not perceptibly bleach them. Traces of ferric salts, such as may gain access to cane-juice from iron mill-rollers or other factory machinery, react with anthocyans to yield brown coloured products akin to iron-tannin compounds. The *tannin* of cane-juice is derived mainly from cane-tops and stem-buds or "eyes." It possesses the chief properties of catechol, or iron-greening tannins. Although not itself a true colouring matter, cane-tannin reacts with traces of ferric salts to form an intensely coloured substance difficult to remove from cane-juices, but amenable to bleaching by sulphur-dioxide, and to complete removal by adsorbent chars.

Saccharetin is an ill-defined pigment that appears to originate in the lignin component of cane-fibre or bagacillo from which it appears to be most readily split by hydrolysis in alkaline media. It may be the same as, or similar to, the yellow or rich-brown pigments that arise when almost any carbohydrate is treated wth an alkali such as lime. It is similar to tannins in many of its reactions, forming deep sepia-brown compounds with ferric salts, and pale-coloured compounds when reduced by sulphur-dioxide.

Conclusions.

From the above account, it will be noted that the cane-sugar manufacturer has to deal with a complex mixture of compounds whose actions and interactions are largely conditioned by the physico-chemical state of the aqueous environment in which they are situated. Slight changes in this environment (temperature, reaction, composition as decided by addition of extraneous substances) may profoundly modify the behaviour of these various components, and may result in the formation of new substances, or in some new orientation. It is only through a full knowledge of the nature of their properties and relationships, that satisfactory control of the processes of sugar manufacture can be attained, and the value of suggested new procedures accurately assessed.

CHEMICAL RESEARCH PROBLEMS IN CANE SUGAR PRODUCTION

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THE following notes are presented with a view to drawing attention to problems awaiting solution or deserving further study and demonstration. Certain of them are receiving consideration at the College, where facilities are now available for the prosecution of investigations into most of the phases enumerated.

Many of the proposed factory investigations, however, require special equipment (different types of strainers, liming apparatus, juice-heaters, filters, &c.), and it is earnestly hoped that makers will submit any such appliances for trial under experimental conditions.

(A)—CANE-SUGAR MANUFACTURE.

1. Studies of existing Factory Processes.

(1)—MILLING.

1. *Micro-organic infection at the mills.*—Much trouble often arises from this cause, mainly through the increase in acidity of mill-juices, brought about by fungal and bacterial activities. Roberts and McCleery (*I.S.J.*, 1925, p. 543) advise washing the mill-train every few hours with small but powerful jets of hot water. Hutchinson and Ramayyer (*Agric. Res. Inst. Pusa*, Bul. 163, 1925) advise sprinkling with a 0.004 per cent. solution of sodium hypochlorite. The use of formalin has previously been advocated, but it is expensive. A 1 per cent. solution of ammonium fluoride has been used to disinfect pipes and machinery fouled with growths of *Leuconostoc*. Liming at the mills has also been practised. These various methods should be compared under controlled conditions.

2. *Efficiency of maceration.*—Penetration of water into the megass blanket is not always thorough. Various devices for forcing in the maceration water have been proposed, and deserve testing (*e.g.*: the roller method of Burunat (English patent), and the use of compressed air or steam suggested by Kessler (English patent)).

3. *Effect of shredders.*—Cane-shredders produce increased amounts of bagacillo which, through hydrolysis, eventually generate additional pentosan in factory juices and therefore augment defecation difficulties. On the other hand, bagacillo forms a good filtering medium at the presses. The relative importance of these factors should be compared, and the value of different *straining appliances* appraised. "Filter-cel" or similar material might be employed to make up the deficiency in filtering body caused by removal by strainers of bagacillo from juices as they leave the mill. (*See* Peck, *I.S.J.*, 1921, p. 158.)

(2)—LIMING.

Realization of the important effects which changes in reaction of sugar-liquors may produce, and the perfecting of methods for measuring reactions, have led to increasing attention to the liming process. The different effects of under and over-liming should be further examined by precise measurements before and after treatment, of the various juice components likely to be affected (total colloids, proteins, pectins, pentosans, glucose, silicate, phosphate). Preliminary work during the past season at the College Sugar Factory has shown that some unexpected results may arise from such detailed studies. Much depends on the methods of liming practised. The value of apparatus for continuous and thorough liming should be tested, *e.g.*: the conduit method of Fleener (U.S. patent), and the rotating disc method of Morse (U.S. patent).

A method is now available for continuous recording of the reaction value of juice before and after liming (Balch and Paine, *Planter and Sugar Manuf.*, 1925, Vol. LXXV., p. 347). This is based on the applicability of the tungsten electrode, and promises to replace colorimetric methods, in which indicator solutions, such as those evolved by Clark and Lubs (Farnell, *I.S.J.* 1925, p. 141.), or test papers, made up with these or other indicators (Geerligs, *I.S.J.* 1925, p. 275), are used. By such means, the more accurate control of the liming process at the liming station should be possible, for the liming station is obviously the place where rapid adjustments of reaction values should be made.

Finally, there is need of definite data on the lime-requirements of juices from different varieties of canes (*e.g.*: hybrid seedlings and Uba), which are known to possess different compositions. (*See* Roxas, *I.S.J.*, 1924, p. 486, and Allen, *I.S.J.*, 1923, p. 587).

(3)—HEATING.

It is still a debatable point whether juice-heating should precede or follow liming. Pre-heating, especially to relatively high temperatures (104° to 106°C), is held by some to effect (*a*) fission of

organo-silicon compounds (Bird, *I.S.J.*, 1923, p. 44, Müller, *I. S.J.*, 1921, p. 579; Farnell, *I.S.J.*, 1923, p. 358), (*b*) denaturation and precipitation of albuminous proteins (Farnell, *I.S.J.*, 1924, p. 333), (*c*) partial dehydration of pectins and pentosans, (*d*) hydrolysis of lignocellulosic components of bagacillo, (*e*) hydrolysis of pentosans into pentose sugars, and (*f*) hydrolysis of phosphoric esters. These various reactions ought to be further examined by quantitative determinations of the several components before and after the juice is heated.

The change in reaction and its effects on juices that have been limed and then heated and boiled for different time periods should also be traced by the application of precise quantitative methods, for it is known that limed juices become appreciably more acid when maintained at high temperature, probably chiefly owing to the oxidation of glucose into various organic acids. In a critical laboratory study, for example, Walton, McCalip and Hornberger (*Ind. Eng. Chem.* 1925, p. 492), found that limed juices liable to be exposed for periods exceeding four hours at boiling-point should possess reaction values above pH 6.7, otherwise inversion of sucrose is likely to occur, and that the best initial reaction for limed juice lies between pH 7 and pH 8, yielding final syrups of reactions pH 6.7 to pH 7.0.

The effect of heating cane-juices for different time periods and at different reactions, on the degree and on the nature of the end-products of hydrolysis of pentosans, and of the lignocellulose component of bagacillo, would appear to be particularly well worth detailed investigation.

(4)—Settling.

The rate of settling and clearing of limed and heated juices is known to be a function of previous treatment and of final reaction, which decide the composition, particle-size and degree of flocculence of the precipitates. Cloudiness of defecated juice appears to be at least partly due to the presence of emulsified "cane-wax" which is chiefly composed of fat), although silica may also be responsible. The properties and behaviour of cane-wax during defecation deserve extended study, for little is yet known concerning them, (*See* Smith, *I.S.J.*, 1924, pp. 266, 322). McCleery (*La. Planter*, 1924, p. 89) states that cane-wax is more easily removed at neutral or acid reactions than under alkaline conditions, and that liming fails to eliminate cane-wax from juices. On the other hand, efficient straining may remove much of the cane-wax along with the bagacillo.

(5)—Filtration of Scums and Sediments.

The factors controlling filtration rate (temperature, pressure, reaction), still remain to be accurately assessed. The value as aids to filtration of bagacillo or of added solids, such as Filter-cel and different earths and clays, deserves further study. The possible advantage of the continuous rotary "stream-line" filter (Armstrong, *I.S.J.*, 1925, p. 424) for filtering limed juice *en masse* requires further examination under factory conditions. The effect of double-pressing (Allen, *I.S.J.*, 1924, p. 30), likewise needs further investigation. Whether or no continuous apparatus, such as the Dorr settler, will completely replace the older apparatus, depends largely on the results of carefully-planned factory research in which all the circumstances are taken into consideration.

(6)—Evaporation in Multiple Effects.

Subjects requiring further investigation under this heading are the composition and properties of calandria condensates (*See* Linden, *I.S.J.*, 1919, p. 351) of evaporator scale (*See* Scott, *T.A.*, 1926, p. 245), and Linden (*I.S.J.*, 1923, p. 637), and of entrained substances that pass out at the tops of the evaporator units (*See* Bardorf, *Canad. Chem. Met.* 1926, p. 175, and Schweizer (*Archief. Suiker.*, 1919, p. 2010).

(7)—Graining and Crystallization.

At present, the control of the vacuum pan is an art rather than a science. Investigation of the various factors that operate to produce any one result, however, is likely to prove extremely difficult. The relative effectiveness in retarding or preventing sucrose crystallization of components such as pentosans, glucose and mineral salts, still remains to be accurately defined. The fall in purity when low-grade syrup is drawn into the pan after a syrup of high purity has become only partly spent through continued crystallization may be so pronounced that the form and shape of the sucrose crystals are profoundly altered, and an uneven sugar results. Similarly, temperature changes may give rise to "false grain." In order to overcome these troubles, Munro (*Austral. P.* 1926, p. 812) has suggested the use of low-grade syrup for forming grain, and successively higher grades of syrup for subsequent additions. This procedure is said to give a very regular and plentiful crystallization.

The conditions governing the formation of "double crystals" require likewise to be elucidated, for possibly double crystals also owe their formation to changing concentration of impurities, as well as to temperature changes.

Particularly interesting should be studies of the effect of reaction value on the rate and manner of crystallization of sucrose in the vacuum-pan, in especial connexion with the use of phosphoric acid and other amendments.

"Seeding" the contents of the vacuum-pan may be performed either with massecuite or with powdered white sugar. The latter procedure has gained favour in many Hawaiian factories. The relative effects and usefulness of these two methods should be critically examined.

In all these studies, physical methods for measuring such properties as density, viscosity and surface tension (by the Du Noüy tensometer or the Traube stalagmometer), should prove of great value. Their applicability has been tested by some preliminary experiments at the College Sugar Factory.

The most suitable treatment of vacuum-pan strikes in coolers and crystallizers for greatest sucrose recovery, deserves investigation.

(8)—Curing in the Centrifuge.

Here again, the physical properties of massecuites appear largely to decide the ease with which they can be separated into crystalline sugar and molasses, and investigations on curing-rate should first be pursued from this stand-point, following the pioneering work of Geerligs. Washing sugar in the centrifuge with syrup, then purging with steam (rather than merely washing with water), advocated by Lesueur (*I.S.J.*, 1924, p. 102), deserves trial.

(9)—Treatment of Molasses.

The treatment of molasses so as to render it susceptible of the further extraction of sucrose, is one of the most important problems of the cane-sugar factory. The effect of blowing-up with steam, of heating and skimming, of liming, of adding soda or soluble phosphates in attempts to remove impurities, have all been recommended, yet little quantitative data relating to their various effects has been accumulated. The possible application of high-speed centrifuges is being investigated. A biological method in which a special yeast is employed to destroy reducing sugars in molasses, has recently been proposed by Paine, Walton and Birchner, (U. S. patent), and is worthy of trial.

(10)—Special Processes.

(1) *Sulphitation.* The chemistry of sulphitation has been studied in the laboratory by Farnell (*J. Soc. Chem. Ind.*,, 1925 pp. 530 T, 533 T). His conclusions should be tested under factory conditions (*See* also *I.S.J.*, 1926, p. 36 and *T.A.*, 1926, p. 74). The "safety limit" of acidity in sulpho-defecation under various circumstances should be accurately determined in the factory (*See* Haddon, *I.S.J.*, 1925, p. 445), and Baissac *I.S.J.*, 1926, p. 370). The common method used in Louisiana, Mauritius and Natal is to sulphur the cold juice, lime to pH 6.8-7.4, and then heat and settle. In Javan factories, on the other hand, the juice is heated to 70°C. before sulphiting and liming, but care is taken to keep the reaction near neutrality. The preliminary heating may effect some coagulation of protein. It may also aid precipitation of calcium sulphite, which is less soluble at 70° than at 30°C. These possible results should be established experimentally. Perhaps the additional use of phosphoric acid to correct excessive alkalinity which may arise during the liming, and to bring the final reaction down to pH 6.8 or thereabouts, would prove highly beneficial. The small amount of inversion caused by sulphiting at 70° may well be counterbalanced by the improved defecation obtained, particularly with respect to the removal of cane-wax.

The *Bach process*, in which liming and sulphiting are applied to hot syrups, is stated to have been tried in Java and Mauritius, but to have been abandoned (*See Journ. Soc. Chem. Indus.*, 1914, p. 935). Baissac (*Rev. Agric. Maurice*, 1925, p. 375; *I.S.J.*, 1925, p. 555) maintains, however, that the method gives excellent results, provided the lime is introduced in small quantities during sulphitation, and provided that the reaction of the syrup is not allowed to rise much above pH 7.0. Armstrong states that he obtained satisfactory results in preliminary trials of the preparation of white sugar by Bach's process, even without the use of decolorizing carbons (*I.S.J.*, 1925, p. 187). Sulphitation was arrested at a slightly alkaline reaction, and phosphoric acid was then added to make the syrup slightly acidic. In this way, undesirable precipitation of calcium sulphate produced by oxidation of calcium bisulphite was avoided. These various conditions making for success in the Bach process, should be more thoroughly studied.

(2) *Phosphation.* Farnell has also studied the chemistry of phosphation in the laboratory (*J. Soc. Chem. Indus.*, 1926, p. 343 T; *T.A.*, 1927, p. 14). He considers that the drop in pH value in cane-juices that have been limed and heated is partly due to precipitation of calcium phosphate which is then hydrolysed to phosphoric acid and to stable hydroxyapatite. He also considers that the natural calcium phosphate component of cane-juices comprises the main buffering system present, whereas other investigators have regarded amino-acids and proteins as the chief buffers.

Cane-juices whose natural phosphate content is above a certain critical value, appear to be most easily defecated by liming. Walker (*Ind. Eng. Chem.*, 1923, p. 164) fixes this critical value at 0.02 g. P_2O_5 per 100 cc. of juice; McAllep and Bomonti (*Hawaiian Planters' Rec.*, 25, p. 122) at 0.03 g., and Farnell, at 0.01 g., but there must be some relationship between the amount and nature of the non-sugar substances present and the critical phosphate content requisite for good clarification. This relationship would appear to be worthy of further investigation, using analytical methods such as those perfected by Springer and Davies, (*J. Soc. Chem. Ind.*, 1927, p. 143 T; *T.A.*, 1927, p. 108). A preliminary study of the subject was made this year in the College Sugar Factory.

Berenger (*Rev. Agric. Maurice*, 1925, p. 336; *I.S.J.*, 1925, p. 557) has studied the conditions under which best results are obtained by the use of phosphoric acid in white sugar manufacture.

The result of superheating untreated cane-juice with a view to decomposing phosphoric esters (such as hexose phosphates) which may occur therein, and thus rendering their phosphate component amenable to precipitation, requires examination.

(3) *Carbonatation.* Farnell promises an investigation into the chemistry of carbonatation, but so far, he has not published any results. The investigation would be well worth while, particularly since it is usually maintained that carbonatation removes considerable amounts of pentosan which evade elimination by most other treatments.

(4) *Silicatation.* The precipitation of the silicate component of cane-juices by liming has never been investigated systematically. Its study should follow the lines of Farnell's researches, and the possible value of adding silicate to juices to aid defecation should be tested. The chief draw-back to "silicatation" as a practicable factory process, is that it is likely to lead to excessive scale formation in the evaporators. How far silicate may replace phosphate in cane-juices, and the effect of such replacement, needs yet to be defined.

(5) *The use of decolorizing carbons in white sugar manufacture.* The efficacy of the various carbons (Suchar, Norit, Darco), now available on the market, in removing colouring matters and mineral salts from raw sugar solutions ("melts"), should be further compared under controlled conditions of temperature, time and reaction. There is some evidence that certain adsorbent chars exhibit iso-electric points at which they are the most active (Kroetz, *J.C.S.*, 1925, ii, p. 191). Animal chars should be compared with vegetable chars. The rôle played by the mineral component of chars in the process of adsorption should be investigated in detail. Davis' synthetic bone char, made from superphosphate, slaked lime and molasses (U. S. patent 1926) is worthy of trial. Much work on these subjects however has already been done; (*See* Honig, *Chem. Weekblad*, 1925, p. 165; *Koll-Chem. Beihefte*, 1926, p. 345; *I.S.J.*, 1926, p. 302; Brewster and Raines, *J. Ind. Engin. Chem.*, 1921, pp. 921, 1043; Blowski and Bon, *I. S. J.*, 1926, pp. 203, 255, 297, 367; *Indus. Engin. Chem.*, 1926, pp. 650, 651; Knowles, *Indus. Engin. Chem.*, 1925, p. 1151; Miller, *J. Phys. Chem.*, 1926, pp. 1030, 1162;).

II.—Studies of New Factory Processes.

(1)—Fundamental Alterations.

Various new modes of isolating sucrose from sugar-cane juice are frequently being suggested. Many of them fail to satisfy the economic requirements of sugar manufacture, but many of them are discarded without proper trial. One of the functions of an experimantal factory should be to test the more plausible of such new methods. Nevertheless this is often impossible because special equipment is required, and such can only become available through the co-operation of engineering firms.

A plant-physiologist, faced with the problem of isolating sucrose from cane cell-sap, would doubtless advise some process which would cause an alteration in the degree of permeability of the cell membranes, so that only true solutes, such as sucrose, could pass through them. Colloidal substances would coincidentally be retained in the cells, and would never reach the extruded solution. Ether, alcohol and toluene vapour are known to effect this change, but their large-scale use would be expensive and difficult to manage. On the other hand, steam or boiling water, used in special diffusion vessels similar to those employed in modern beet-sugar factories, may be nearly as effective, and would be easy to apply. Whenever and wherever the fuel question can be solved without the need of megass, this type of diffusion extraction would doubtless become practicable. The possibilities have been discussed by W. Scott in an article in this "Supplement."

(2) Use of New Reagents.

Zerban (*La. Planter*, 1920) demonstrated that Filter-cel together with Norit give satisfactory clarification of cane-juice without the use of lime, but, as far as the writer is aware, the process has not been extensively practised in large factories. Probably the high price of decolorizing chars is prohibitive. Various other adsorbents have been suggested as substitutes for lime, for example, hydrous alumina, hydrous magnesia (Ishida, *Formosa Bul.* I, 1920), calcium carbonate and sulphite (Lourens, *Arch. Suiker.*, 1924, p. 1438), hydrous alumino-silicates (Wells, *La. Planter*, 1923, p. 394), and various other hydrous oxides, tannates and gelatin-tannins (Hebden, U.S. Patent, 1926). Certain of these are worthy of further study. Lateritic clay and bauxitic clay, containing hydrous alumina, offer promise, but appear not yet to have been tried.

The use of pepsin at slightly acid reaction has been recently advocated by Schreiber (*Ind. Engin. Chem.*, 1926, p. 860) as an agent for destroying proteinous matter in beet juices. Possibly papain from the tropical fruit, Papaw, may exert similar effect on cane-juices.

Chlorine and hypochlorous acid have been proposed as decolorizing agents for application to cane-juices and syrups. (Ochi and Kotera Engl. Patent, 1926; *Trans. Amer. Electro-Chem. Soc.*, 1926, p. 147). Their usefulness ought to be determined.

III.—Laboratory studies of Identity, Properties, and Behaviour of Components of Cane-juices and Syrups.

Much further laboratory research on the components of cane-juice by competent organic and bio-chemists is needed. The exact identities of hemicelluloses, pentosans, pectins, proteins, amino-acids, "fruit" acids, carbohydrate acids, colouring matters (especially "saccharetin" and brown humous substances, including "caramel," as well as their oxidation products), waxes, fats and soaps, which occur in factory liquors, have not yet been completely determined. Phosphorus and silicon compounds deserve special investigation.

Hydrolysis studies of megass, bagacillo, hemicelluloses, pentosans, pectins, and the organo-phosphorus and organo-silicon components of cane-juices exposed to different temperature, time and reaction conditions, should be made in the laboratory.

Many of the suggested new reagents or processes might first be put to laboratory trial before they are introduced into the factory.

Finally, improved methods for accurately and rapidly determining the various substances

present in cane-juices and factory liquors are urgently needed. Their elaboration is a necessary prerequisite to further detailed investigations of processes of sugar manufacture.

B)—SUGAR PRODUCTION IN THE CANE PLANT.

Physiological and biochemical researches into the factors that control the synthesis, transformation and translocation of sugars and other substances in the cane-plant, growing under various environmental conditions, have not yet been attempted on a sufficiently large scale to furnish conclusive data. Little is known of the fundamental physiological processes that go on in the cane plant. Their study by modern biochemical methods involving dynamical and statistical considerations, should yield far-reaching results. Work of this nature on the cotton-plant is at present being carried out at the new Cotton Research Station in Trinidad, by Drs. Mason and Maskell, and their procedures and methods could with advantage be applied to the sugar-cane.

(1) Different varieties of cane should be compared as regards their physiological and biochemical differences both in health and in disease.

(2) The process of ripening should be followed by similar methods, and the effects of tillering and arrowing similarly traced.

(3) The rôle of hexose phosphates, of organo-silicon compounds, of asparagine, of acids, of cane tannin, and of waxes and fats in the growth-processes and in the resistance of the sugar-cane to adverse external circumstances should be discovered.

(4) There is doubtless some close connexion between soil conditions and sugar-cane growth and metabolism.

(*a*) The possible relation between *phosphate* in soil and phosphate in the cane-plant deserves especial study because of its importance in the factory behaviour of cane-juices. Walker (*La. Planter*, 1922, 70, p. 127) obtained some positive correlation between phosphate added to a soil and phosphate in juice of canes grown in that soil. Pratt (*Haw. Plntrs. Rec.*, 1924, 28, p. 34) failed to confirm this finding in his experiments in Hawaii, but he demonstrated that different varieties of cane are characterized by different phosphate contents of their juice. In experiments of this type, however, it should first be ascertained that phosphate manuring of soil really has increased the rate at which phosphate can enter the plant.

(*b*) The *potassium relation* between the sugar-cane plant and its soil environment appears to be of particular importance in connexion with carbohydrate metabolism, and with resistance of the plant to certain diseases, although in the latter connexion, the magnesia : lime ratio, stressed by Bird (*I.S.J.*, 1925, pp. 423, 536), may also be of moment. These factors deserve intensive study.

The sugar-cane is notably a "potassium plant," its ash normally contains nearly 90 per cent. of potassium and sodium salts, and only 10 per cent. of salts of calcium and magnesium (Liebig).

(*c*) The *calcium relation* of the cane-plant, apart from its effect on soil reaction, is obscure. Liming experiments in all parts of the world where sugar-cane is grown have demonstrated that liming does not generally increase cane production. The cane-plant may be regarded not as a lime-loving plant, though tolerant to lime Excessive lime in soil, however, leads to marked foliar chlorosis. The possible relation between wax and fat formation and distribution over the plant surface, and calcium content of soil, has not yet been tested (*see* Hardy, *T. A.*, 1924, p. 189). Its significance in drought-resistance may be considerable.

(*d*) The *nitrogen relation* between cane plant and soil is fairly well understood. The fact that the sugar-cane can utilize nitrate-nitrogen but not ammonia-nitrogen, seems to have been definitely proved by McGeorge in Hawaii (1923). This implies that, unless conditions are suitable for the rapid conversion of ammonium salts into nitrate through the agency of specific soil bacteria, (nitrification), the use of these salts for manuring sugar-cane is not likely to be remunerative. Nitrification in soils takes place best at neutral or alkaline reactions.

(*e*) The *acidity relation* requires much more detailed study than has heretofore been afforded it. The subject is extremely complex, since the degree of acidity of the soil is nowadays regarded chiefly as a factor conditioning (i) the processes that go on in the absorbing-cells of the root, (ii) the rate of production of available mineral nutrients in the soil, and (iii) the activities of soil micro-organisms that control nitrogen transformation. When excessive (say below pH value 5·5) soil acidity, under certain circumstances, may cause the liberation of harmful amounts of aluminium, iron and manganese. (McGeorge, *Haw. Sugar Planters Assoc.* Bul., 49, 1925 ; Hardy, *J. Agri. Sci.* 1926, p. 616.) This may result in tissue disintegration, and root-rots in the cane plant.

(*f*) The *water-relations* of the cane-plant have always been considered as fundamental in cane agriculture (*see* Koenig, *I.S.J.*, 1923, p. 643). The value of irrigation has long been appreciated. For every pound of dry matter produced by the cane (or 2·8 lb. of fresh green material), some 500 pounds of water are transpired. Hence, a well-distributed rainfall, of at least 60 inches a year, is required to yield large crops, unless irrigation is practised, and assuming that all the rain-water is utilized by the crop. (Fox, *Sugar*, 1923, p. 138). Detailed field studies of the water relations between the sugar-cane plant and various kinds of soil, as affected by drainage, exposure, tilth, organic matter, &c., are needed to give greater precision to this water question.

(*g*) The *humus-relation* of soil and cane-plant appears to be somewhat puzzling, if considered apart from the water question. Cane

planters in Barbados believe in the use of sheep manure, though the quantities used seem to be too small to increase greatly the water and nutrient-supplying powers of the soil. Perhaps the ascribed beneficial results are due to micro-organic inocculation. The subject deserves the attention of a soil microbiologist.

(C)—METHODS OF SAMPLING CANES BEFORE REAPING.

There is great need for better methods of sampling canes for ripeness during the crop season. To be of practical value, a sampling method must be rapid and easy. Nevertheless, if the error involved be great, the method would not be worth applying. Research is needed in order to evolve a really satisfactory procedure. The possibility of employing a hypodermic syringe for abstracting a little of the sap from various parts of the stems of stools located in different areas within a field, and the rapid examination of the liquid by the use of a portable refractometer, does not seem yet to have been tried. Alternatively, cores of cane-tissue, cut by the cork-borer, and the liquid content squeezed out through cloth onto a refractometer slide, might, furnish even better samples. In any case statistical studies of the methods evolved in order to define their limits of accuracy, should always be undertaken.

Kashinatha (*J. Madras Agr. Students U.*, 1923), considers that when the ratio of the Brix degrees of the juice from the top and the bottom halves of a cane is unity, the cane may be regarded as ripe.

(D)—DETERIORATION OF SUGAR-CANES.

(1)—Before Reaping.

(*a*) *Effect of pests and diseases.* Further work is needed to assess the damage done by pests and diseases, and to refer it to the various plant-tissues, cell-components, or physiological processes that are affected. Investigation has shown for example, that moth borers cause significant decreases in sugar production. Williams (*Sta. Agron. Guadeloupe*, Tech. Bul. 4, 1926) calculated the loss due to ravages of a moth borer to be over 5 per cent. of the recoverable sucrose of the cane, through diminished juice-purity. This result is substantiated by similar data obtained in Trinidad.

(*b*) *Effect of cane fires.* The damage done to the cane may be considerable (*see* Pratt, *I.S.J.*, 1926, p. 420), or it may not be very pronounced if the prevailing temperature is low. (Cross, *La. Planter*, 1925, p. 308.) The effect of conditions should be further investigated.

(2) After Reaping.

Losses in cut-cane left in the field or factory yard are often very great. Scott (*T. A.*, 1926, p. 34) found losses in available sucrose of approximately 5 per cent. in 1 day ; 10 per cent., in 3 days, and between 15 and 27 per cent. in 6 days. (*See* also Cross, *I.S.J.*, 1926, p. 245, and Pellet, *S. A. Sugar J.*, 1924, p. 336.) Such figures indicate the great need for speed in transporting canes from field to factory. Additional data for other countries and for different varieties of canes grown under various conditions, and for cut-canes exposed to different degrees of atmospheric humidity, would be valuable.

In compiling these notes, the writer has benefited by suggestions freely offered by Professor W. Scott, Mr. R. G. W. Farnell and Mr. R. Follett-Smith, and by Messrs. H. B. Springer and J. G. Davies (fourth year students). To these gentlemen he wishes to tender his appreciative thanks.

ORGANIC MANURES FROM SUGAR-CANE.

The Utilization of Field and Factory Refuse.

BY

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THE profitable utilization of field and factory refuse is one of the most important problems in modern sugar-cane agriculture. Among the available waste products are cane-tops, weeds, grass and roughage, cane-trash, cane-megass, filter-press mud, low-grade molasses, scums and skimmings, boiler ash and clinker, flue and stack dust, fermentation-vat sludge, lees, machinery and floor washings, and animal excreta. Usually these waste-products are either left on the land to rot, or relegated to tip-heaps, or diverted down drains to rivers and the sea. Even when some attempt is made to make use of them, the methods practised are wasteful or even harmful, the main object in many cases being merely to dispose of the refuse with the least possible trouble.

In considering the various methods whereby waste products may best be utilized, primary consideration should be given to their possible rôle in the problem of fertility maintenance in sugar-cane soils. It is a fitting adage that everything that comes from the soil should be returned thereto.

(1) THE UTILIZATION OF WASTE VEGETATION.

Apart from material used as stock-fodder, vegetable matter left on the land is liable to decay in a manner which leads to losses in substances of nutritional value to crops. Furthermore, fresh green material merely turned into the land often ferments in such a way that little true humus is formed from it. On the other hand, dry vegetable matter is difficult to incorporate, and it may temporarily deplete the soil of nitrate-nitrogen. Hence the most satisfactory way of dealing with waste vegetation is to treat it by processes that will preserve its nutrient components, and convert its cellulosic substance into valuable humus. There are various means for doing this.

(*a*) *Pen manure.*—A time-honoured procedure, well known to everyone, is to use the waste material as bedding for stock, and thus to make pen manure from it. The biochemical processes whereby litter impregnated with animal excreta becomes changed into pen manure through the agency of certain micro-organisms, need not be discussed again in this place. Careful study of these processes at the Rothamsted Experimental Station has led to a complete understanding of the fundamental facts underlying the mechanism of their action. Moreover, it has led to a feeling of confidence that satisfactory pen-manure can be manufactured without the intervention of farm animals. This departure from the belief that the virtue of pen manure lies entirely in its formation through the operation of mysterious and uncontrolable processes, marks really important progress.

(*b*) *Synthetic pen manures.*—We now know that, given a suitable *nidus*, certain ubiquitous micro-organisms can convert waste vegetable matter into material that resembles pen manure in all its valuable properties. The conversion requires certain well-defined environmental conditions, such as a suitable water-content, a suitable degree of aeration, the presence of sufficient base to neutralize acidity, and sufficient food material, notably nitrogen, to satisfy the needs of the organisms.

In a pen manure heap, the requisite nitrogen is supplied by compounds contained in animal excreta. In a synthetic manure heap, the nitrogen is added in some other form. There is no advantage to be gained by greatly increasing the amount of nitrogen in any case, as the believers in heavily cake-fed bullock manure have discovered. Generally, in a pen manure heap, the amount of nitrogen added in excreta is more than enough to satisfy the nitrogen requirements of the micro-organic flora needed to convert the whole of the cellulose of the litter into manure. Recognition of this fact has led to the development of the *Mauritian pen manure system*, whereby a smaller admixture of animal excreta with waste vegetable matter of the sugar-estate is allowed than ordinarily obtains in the preparation of normal pen manure. (*See Tropical Agriculture*, Vol. I, 1924, p. 116.)

The nature and composition of the waste vegetable matter employed in the making of manure heaps, quite apart from considerations of the nitrogen question, introduce additional factors of great importance. Cellulose-decomposing organisms require (besides nitrogen) organic food-stuffs of the nature of simple carbohydrate substances, such as gummy pentosans, starches and certain sugars. Different vegetable materials contain different amounts of suitable carbohydrates, and many of them resist breakdown because of their deficiency in these compounds, and because of their high content of fibrous, woody

cellulose. Thus, cane-tops, cane-trash, and succulent weeds and grasses are quite easily broken down, because they contain relatively high percentages of the simpler carbohydrates (between 40 and 55% of the total dry matter), and low percentages of resistant woody cellulose. On the other hand, cane megass, scrubby weeds and woody bushes contain much smaller proportions of the simpler carbohydrates that are needed as food for the micro-organisms, and much greater proportions of resistant woody cellulose. They are therefore less easy to break down, and seldom form satisfactory manure, unless specially treated.

(i) *" Adco " manure.* In the " ADCO " *process,* decomposition of waste vegetable matter is accomplished by artificially providing the right conditions for the growth of the proper micro-organisms which are always naturally present in sufficient numbers thoroughly to infect the heap. (*see Tropical Agriculture,* 1925, p. 108, Vol. II.) The patent mixture made by " ADCO " Limited, contains sufficient extra nitrogen and neutralizing base to satisfy all requirements.

(ii) *Distillery sludge manure.* Theoretically, certain nitrogen compounds other than those used in the manufacture of " ADCO " mixture ought to serve the same purpose, although the resulting manure may not be so well balanced. We have seen that the nitrogenous components of animal excreta (chiefly urea) are adequate and suitable. It appears possible that the nitrogen compounds present in distillery sludge (consisting mainly of dead yeast cells) and factory skimmings, might also prove suitable and adequate. The important preliminary trials performed by Mr. V. M. Hinchy at Caroni Estate, Trinidad, and described in *Tropical Agriculture,* July, 1927, certainly demonstrate that this contention is not unreasonable, provided all the requisite conditions are observed.

(iii) *Filter-press mud manure.* Perhaps filter-press mud may be used instead of distillery sludge in making synthetic manure from waste vegetable matter of sugar estates. It certainly is worthy of trial, either alone or mixed with other nitrogenous materials.

(iv) *Compost manure.* A further extension of these suggestions points to the possible utility of making compost heaps from most of the waste materials enumerated at the outset. The basis would be cane-trash, scrub, grass, and surplus megass. The extra nitrogenous components would be distillery sludge, filter-press mud, and even molasses. The water required could be added as lees and factory skimmings. If the compost heap were made in the open, rain-water would serve to make up deficiencies, but it would be advisable to guard against excessive leaching, otherwise valuable ingredients such as potassium compounds, might be lost.

In order to render a compost heap more open and permeable, boiler-ash and stack-dust might be sprinkled over the layers of vegetable matter as the heap is being constructed. The procedure is certainly worthy of extended trial, for it would adequately deal with large quantities of waste matter, and would convert all of them into a manurial material whose composition and condition would render it eminently suitable for direct application to the land.

(2) ECONOMIC CONSIDERATIONS.

The chief requisite of any system of manure manufacture is that it should be practically feasible and reasonably cheap. In making ordinary organic manure in stock-pens in the estate yard, fodder and litter must be carted from the fields, traces and waysides, and provision made for the sheltering and watering of the farm animals. Furthermore, the finished manure must be carted out again at the correct time to the places where it is to be applied. The transportation costs are thus liable to be very high, especially in estates that are not provided with efficient railway-systems or with adequate roads. Consequently, fields remote from the yard are liable to be neglected when the manure is distributed.

To overcome these objections, field-pens are frequently advocated. For field-pens to be satisfactory, the breed of stock should be one capable of resisting exposure to weather. Furthermore, an adequate water-supply in the form of streams or ponds must be easily available, and the stock-keepers must be reliable, for decentralization reduces opportunities for strict supervision.

These conditions are not materially altered when the Mauritian system is practised. They may even be aggravated, in that chopping machinery and attendant mechanics are needed, in addition to extra labourers for transferring the manure from pen to pit.

On the other hand, synthetic manure making is less exacting. Provided adequate water-supply is available, synthetic manure heaps may be constructed in fields where the manure is subsequent to be applied. Where the periods of rainy weather synchronize with the times when the waste vegetable material can be stacked for watering, considerable saving, however, may be effected. The main problem to be solved in the manufacture of synthetic manures is therefore the collecting and the wetting of the heap. Apart from the cost of the mixture itself, " ADCO " manure offers great possibilities as a system of manure making on sugar-cane estates.

Where distillery sludge or filter-press mud is used as a possible substitute for " ADCO " mixture in the preparation of synthetic manure, the question of its transportation from factory to field is necessarily introduced as an additional factor.

There appears to be no reason why a critical examination based on accurate costing and aided by chemical analysis, should not be made of the various proposed methods for manufacturing synthetic manures from sugar-cane field and factory waste-materials, on those estates where facilities permit. By such means, the most economical procedure will readily be revealed. There is no doubt that the practice of growing sugar-canes on land whose fertility if suffering progressive depletion through continuous cropping will eventually end in disaster.

INSECT PESTS OF SUGAR-CANE

BY

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SUGAR-CANE wherever grown is subject to attacks of insects, some of which in every country occur in sufficient number to cause serious losses, and consequently are to be classed as important pests.

Every cane-growing country has its moth borer. The insects in the different countries are not always of the same species, but throughout a wide range, insects closely related and of similar habits are responsible for serious losses and injury to the growing cane.

In other instances the insect or insects occurring in a given locality may be of a species or a group of related species which occur as pests in that locality and may have no economic significance in other places.

The small moth borers which occur as pests of the cane during the whole of its growing period are examples of the first of these groups, while insects such as the root borer of sugar-cane in Barbados and the froghopper in Trinidad are examples of the second.

Some of the insects attacking sugar-cane are adequately controlled by their natural enemies; in other instances although natural enemies occur, and sometimes in abundance, the degree of control exercised does not appear to be at all adequate and in still other cases no natural enemies of value are known to exist.

The situation in Trinidad with regard to sugar-cane pests is rather remarkable. Only one insect attracts the attention of the sugar planter generally, and that is the froghopper. Other insects occur attacking sugar-cane, but the damage done by them is for one reason or another not very serious.

In the West Indies generally and in British Guiana the small moth borers constitute the most serious and persistent of all the sugar-cane pests. In Trinidad, however, although these insects are generally distributed throughout the island, planters as a rule do not recognise the small moth borer as a pest of importance.

In Barbados, in addition to the small moth borer, there occurs the root borer, the larva of a large weevil which is responsible for serious losses at the ripening period in most seasons. Also, in Barbados, the grubs of the brown hard-back occur in the soils of the cane fields in large numbers. The amount of damage done by this last-mentioned insect has never been determined in Barbados, but it is the same insect that for several years was such a severe pest in Mauritius.

In other cane-growing regions similar conditions exist. In Australia, soil grubs, the larvae of certain beetles, occur in great numbers and their control constitutes one of the great problems in connection with sugar-cane production. Extensive trials with insecticides have yielded results indicating that these pests may be satisfactorily controlled. In Hawaii, a few years ago, the cane fly threatened the very existence of the industry until the natural enemies introduced from the country of its origin reduced the pests to a position of comparative insignificance. The weevil borer of canes in the Islands of the Pacific and Australia is a serious pest attacking healthy canes and causing great injury, while in the American Tropics a very similar insect is noticeable only in canes that have been injured so that the rind is broken and the soft inner tissues are exposed to attack.

The white grub attacking canes in Mauritius was introduced into that island, probably from Barbados, and for a time threatened the existence of the cane industry. The introduction of the parasite of the grub from Barbados has resulted in restricting the severity of the attack very considerably.

In Trinidad, the froghopper of the sugar-cane has been the subject of extensive study for several years. In the first instance it was considered purely an entomological problem but more recently the froghopper question has been recognised as being a subject of great complexity. The influence of varying climatic conditions, including the length and intensity of the dry season and the distribution of the rainfall, all affect the conditions of the soil, the growth of the plant, and the development of the insect. The degree of humidity appears to affect the breeding of the insect and the abundance and virulence of attacks by the fungoid parasites of the insects. With the exception of a parasitic fungus, the natural enemies of the froghopper do not appear to be of interest in this investigation. There are stages in the development of the insect when insecticides may perhaps be used to good advantage as a control measure.

The complexity of the investigation into the froghopper as a sugar-cane pest is indicated by the foregoing remarks. It involves a knowledge of the life history and insect development under the varying conditions which exist in a locality where the seasons vary and the amount of rainfall is not constant either in its amount or in its distribution. The use of insecticides, the value of natural enemies, and the relation between the growing plant and its environment and the effect of this relation on its response to its insect enemies are subjects for research.

The Imperial College of Tropical Agriculture in collaboration with the Department of Agriculture and the sugar planters of the Colony have undertaken an investigation into the whole subject of the froghopper and its control. The work has been already well started, observations have been made and careful records have begun to accumulate. Studies in soil science, in the use of insecticides, and in the value of the parasitic fungus are well under way. The blight which usually follows froghopper attack, often causing extensive areas to look as if burned by fire, appears to be a physiological or bio-chemical result. The effects of drainage and of drought, of tillage and of manures become subjects of enquiry in this research.

Froghopper is an important problem in Trinidad and the need for investigation is pressing. It is of local importance, but it is of so complex a nature that its solution, or even the studies leading towards its solution, should furnish valuable data on other subjects relating to sugar-cane and other crop plants.

The conditions under which sugar-cane is grown in the tropics, with an over-lap of crops each year indicates that biological control of pests, that is, the use of the natural enemies such as predators, and parasites among the insects, and parasitic fungi, is likely to be a profitable line of investigation for the future. In fact, several striking instances of success have already been recorded. The cane leaf hopper in Hawaii and the soil grub in Mauritius already mentioned are examples. The weevil borer in the Pacific Islands is being controlled to some extent by a parasite. The small moth borer in Trinidad appears to be controlled by its natural enemies to a considerable extent. In British Guiana the same parasite occurs in great numbers without exercising any effective control, but this is thought to be the result of different estate methods, particularly burning of the cane trash. In British Guiana for several years the Giant Moth Borer was a most serious pest. The same insect is now said to be increasing in abundance in Trinidad.

The causes of increase or decrease in abundance of pests and the effect of natural enemies are subjects for investigation. At present efforts are being made to introduce the Braconid parasites of the moth borer from British Guiana, where they are abundant into Barbados and Antigua, where they do not exist. If this is successful these colonies may become the source of supply for other islands. The Tachinid fly parasite of the small moth borer, abundant and effective in Porto Rico and Cuba, may be introduced to the Lesser Antilles later.

The control of pests of sugar-cane comprises a range of subjects for investigation in which the College can help and is at present helping. Any results obtained in Trinidad and other West Indian localities will be almost certain to throw light on similar problems in other places. The problems nearest to hand will naturally be the first to be studied and as others become more pressing and as staff and funds become more readily available other problems can be taken up. The West Indian group of sugar localities has its general pests, while the localities have special problems. The field for investigation is interesting and the means for research study are being developed.

MYCOLOGICAL AND BACTERIOLOGICAL PROBLEMS

BY

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APART from the investigation into the economic possibilities of the green Muscardine fungus (*metarrhizium anisopliæ*) as a factor for controlling the Froghopper pest of Sugar Cane in Trinidad no special mycological research work has been undertaken by the college staff on sugar in the field or factory. This is due to the fact that there is, up to the present, only one member of the staff of the Mycological Department, and he has decided to investigate problems in other crops, the solution of which appears to be of more immediate importance

When the Staff is increased there is ample scope for biological research in the sugar cane industry. Several problems await elucidation in the field and the factory. In the field the pathological problems to be studied in the College must perforce exist in Trinidad. The island presents two most interesting, difficult, and important problems, and their solution may have far reaching results, not only in sugar cane culture, but in other equally important tropical crops. The first of these is the Root Disease. Several fungi are held responsible for root disease of sugar cane in different parts of the world. The relative importance of these organisms is not thoroughly understood. It is agreed, however, that the various forms of root disease have one point in common, namely, that the *prima causa* of the affection is non-parasitic in its origin. This being so it follows that the explanation, for example, of the epidemic of root disease on the Bourbon cane in the West Indies must be to a great extent something apart from any inherent susceptibility of this variety to the effects of fungous activity. A detailed study of the sugar cane and the various fungi associated with root disease on a physiological basis cannot help but bring to light facts of the greatest importance. The second important field pathological problem is the Mosaic Disease. Tobacco and various other crops are also subject to this class of disease, and the results of research work on the widely spread Mosaic disease of sugar cane would, with or without slight modifications, be applicable to other crops grown not only in the tropics but also in temperate climates.

One of the by-products of the sugar cane industry is rum. The quality and flavour of rum manufactured in different parts of the world vary tremendously and there seems to be more than one reason why this should be. Different methods of manufacture are used in different parts, climatic conditions vary and this latter must affect the kinds and numbers of the micro-organisms which bring about fermentation. Furthermore, seasons vary tremendously at different times of the year in the same places. It is the common knowledge of mycologists that these seasonal changes are coupled with a change in the air borne flora. An investigation into the influence of these changes in temperature and in the flora might explain the diversity of results obtained in some factories from time to time. Crude culture work is carried out in some places under the name of "pitching" and it is a matter of considerable importance to find out how far more refined methods would prove economically sound.

Tremendous losses are caused in manufactured sugars as the result of the activities of micro-organisms. Methods for the prevention of a great deal of these losses are known as the result of research in the Louisiana Experiment Station and elsewhere, but it remains to be seen whether further work will not result in the finding of more effective and cheaper methods.

A biological study of the by-products of sugar cane which are admittedly not used to the best advantages at the present time is well worthy of serious consideration. In this connection one need but mention the possibilities along these lines of converting cane trash into pen manure. The value of "Adco" in this connection will possibly be dealt with under another section, but it should be pointed out that a study of the nutritional requirements and physiological processes of micro-organisms in the tropics might quite possibly result in the production of a different although somewhat similar product which would yield far better and cheaper results than "Adco."

HEALTH AND EFFICIENCY

BY

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THE Department of Hygiene of the Imperial College of Tropical Agriculture was brought into being by the financial aid of the International Health Board of the Rockefeller Foundation.

The work of the Board has produced wonderful results in the control and elimination of yellow fever, malaria and hookworm, and it has stimulated the development of public health administration and has helped to awaken the interest of the masses all over the world in the fact that much sickness, physical and mental deterioration and loss of efficiency can be prevented, and that prevention is really a cheaper proposition economically than the latter attempt at cure. In the minds of some people still there lurks the idea that the sole function of a medical man is to treat sick people. That, of course, is a fallacy, and the preventive aspect of medicine will grow at the expense of the curative side, especially in the Tropics, where apart from climatic factors much of the disease is due to invasion of the body by animal or vegetable forms which are often carried by insects.

The food supply of the world has only increased about one per cent. of recent years and there is insufficient food produced in the world at the present time properly to feed all its inhabitants. Ultimately, as Gorgas predicted, even the people of the temperate climates will look to the Tropical regions for their food supply and the great river valleys of those regions will have to be developed ; but in the intensive growth of animal and vegetable life in the Torrid Zone lies at once the resources and the barrier, because much of this life is parasitic, and animals, plants, and man, become involved in the struggle in which the teeming lower forms of life, such as bacteria and protozoal organisms, want to grow at the expense of the more highly developed living things. Here man, in order to achieve the mastery, must learn by scientific research how to control and balance all these forces and then apply it that he may live and conquer.

Much has been done in recent times to solve these problems. The extirpation of yellow fever from this part of the world is one of the victories, but much remains to be done. Venereal diseases that lower working efficiency and often produce premature death or a weakly second generation must be checked. Tuberculosis can be lessened. Typhoid and other chronic carriers should be prevented from handling food. Malaria control should be carried out along more specific lines. For example, there are nearly one hundred different species of mosquitoes in Trinidad alone and of these only about twelve are Anophelines. Of these twelve Anopheline species only three would appear to carry malaria, and of these, three, according to work done recently, only one species is a really efficient carrier and it has definite breeding proclivities as to season and type of water, so that a study of the infectivity rate and the bionomics of the species that actually carry malaria in a country will give knowledge that will lower the cost of any malaria control undertaken in that country to a considerable degree.

Evidence has accumulated to show that defective diet—apart from actual deficiency—has a great deal to do not only with child mortality but also directly and indirectly with the diseases and mortality of the adult labouring classes.

This question of defective diet is one that affects not only the labourer but also his employer from the direct viewpoint of work output, and is one in which the estate owner can co-operate with the Department of Hygiene in order to track down the cause and effect and ameliorate the condition. Filariasis, fortunately, does not afflict Trinidad, but for the neighbouring countries there remains the problem of not only how the basic condition can be cured, but more especially how the train of circumstances leading on to Elephantiasis can be averted. Trinidad has a statistical reputation for a high death rate from nephritis or inflammation of the kidneys it being third in cause of death, and it is often considered that there must be local factors operating to produce it. With the helpful co-operation of the Government Medical Service the Department is now investigating this condition. Many similar problems remain to be solved—the solution of which would not only produce an increased span of life and output of work for the worker, but also an economic gain to the employer. It is greatly to be hoped that planters will take advantage of the work of the Department and also co-operate with it in its task of increasing the health and consequently the efficiency of the agricultural labourer.

COSTINGS AND RECORDS

An Aid to Management.

BY

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GOVERNMENT help in the form of tariffs, preference and bounties has an important influence on the rate of profit in sugar-producing countries and at the same time has an effect in determining the distribution of the sugar industry. Most producers have some sort of monopoly in the home market, but, so far as the United Kingdom is concerned, the stabilised preference accorded to Empire sugar producers is by no means such as to secure to them the home market. The British Government has not been so ready as others to extend aid to the industry and British producers look to cost reduction for increased returns.

With slightly different wording, paragraph 90 of the Report of the West India Royal Commission is still representative of the British sugar position :—" As we are unable to recommend the imposition of countervailing duties on beet-sugar, or the grant of a bounty on cane sugar produced in the West Indies, and as at the present there seems no likelihood of so considerable and permanent rise in the price of sugar in the ordinary course of events, it is obvious that if the sugar-cane industry is to be restored to a condition of prosperity, this result can only be obtained by reducing the cost of production, unless indeed the bounty system be abandoned by the countries which now maintain it." At present the whole of the sugar producers of the Empire suffer from state-aided competition. Fiscal aid, whether extended to cane or beet, has replaced the political aid then given to the continental beet-sugar industry. Reduction of cost, however, still remains good, if obvious and rather fatuous advice.

Many of the problems connected with cost reduction are scientific and technical, but on the administrative side, there is much to be expected from the recording, analysing, and comparing of terms of expenditure.

In most agricultural enterprises little has been done on these lines. Accounts may have been kept which do at least give a record of disbursements, receipts, and profit or loss, but the analysis of these figures for purposes of management is a comparatively recent development. The absence of such control is largely a legacy of the small estate : the early planter was usually averse to books and in any case he could attain the same results by relying on his personal knowledge and experience. With the increase in the size of the business unit, however, new methods of control were required, and, although reliance on individual experience is still a basis of management, the tendency to supplement this by records is on the increase. Thus we find on some of the larger estates, elaborate and efficient systems of cost accountancy have been in use some time and in all cases have proved beneficial.

A complete system would necessarily be elaborate, but where this would be difficult to carry out, many good results would follow from a partial system which would enable the management to exercise some control over important elements of cost. It is not claimed that the introduction of records would work wonders in the way of cost reduction but it would certainly sharpen the tools of management and render them more efficient.

Many cost differences are, of course, due to unavoidable causes. A favourable supply of labour, for example, makes labour costs in Java considerably lower than in British Guiana. Natural differences in climate, soil and situation also help to increase or decrease cost. A tariff itself may finally give a country a cost advantage : the guarantee of a protected market for sugar may put an industry in a much more assured position and encourage investment of capital. With improved factory and field equipment acquired as a result, various economies in production may be effected.

In many other respects, cost variations which occur between sections of the same estate, between estates within the same area, and between different areas, are avoidable, and the minimising or elimination of such differences is one of the reasons for keeping records.

It is not the object of this article to describe a system of accounts ; from one estate to another, method will differ according to local conditions and personal taste, but the underlying principles will be the same—direct allocation of prime costs and the allocation of on-cost on some reasonable basis. The original entries from which the cost sheets are built up will be found in the labour books of the overseers which record task and pay, from the stores requisitions, from the records of the utilisation of stock, transport and implements, and, so far as on-cost is concerned, from the

financial accounts. It should be understood that the keeping of such accounts and their analysis for costings purposes is not an end in itself; their interpretation is far more important. It is, of course, interesting to know the cost of production of a ton of sugar and to know how it has been built up, but the scrutiny of the elements of this cost, the consideration of their reasonableness and the possibility of their reduction should be undertaken by the manager in order to enable him to direct his operations with greater knowledge.

Labour and supplies are important elements in cost and an account of the way money spent on these items is distributed is necessary for economic management. It is desirable to know the labour cost of different operations in different sections of the estate. Undue variations from what seems reasonable then stand out and lead to investigation. Unless they can be explained by conditions peculiar to the section or estate, it must be presumed that some mistake has been made. Experience has shown that the introduction of analyses of labour records on estates quickly gives a salutary check on expenditure. On one estate the cost of weeding in a section was unduly high; the analysis of the field book showed that the acreage put down as weeded was larger than the area of the section. In another place the cost of carting and delivery of manure from the central dump bore heavily on the outlying sections. A comparison of relative costs showed that, taking all things into consideration, the substitution of cattle pens at various points over the estate was more economical than the maintenance of one central pen.

With regard to the organisation of labour; experience tells that a numerically stable and continuously employed labour force is likely to be more efficient, more orderly and easily managed than a force fluctuating according to seasonal demands. By studying existing variations in conjunction with the records it may be possible to make employment steadier by a little re-arrangement. In a longer period, it will be possible to arrange that certain operations which do not call for immediate attention shall be carried out between those times of pressure that continuous cultivation calls for. Of course, an estate with any claim to efficiency attempts to do this already, but such attempts would be rendered easier and more efficient by record keeping.

Considering now stores and supplies. Taken singly, the various requisitions may not amount to much, but there always is the common-sense tendency to slightly overestimate needs and that same tendency to retain the surplus for future requirements. Consequently, supplies may be on hand in one section of the estate when they are needed in another and when there are no stocks on hand in the supply department. Again where no systematic check is kept, a premium is put on wastage. From the records of purchases, issues, and returns, stores on hand can be checked from time to time, and the analysis of issues will show the amounts taken by different sections of the estate and the use to which they are put.

In practice it has been found that as a rule a single central store is more efficient than separate stores for different departments—factory, cultivation, transport—or different sections, and at least one reason for this is that the amount of work to be done is such that a better paid, more responsible, and more efficient store-keeper can be employed.

Copies of the analysis of expenditure on labour and supplies within a given time on different sections should be issued to the overseers of those sections; this will give them some criterion upon which to work and will provide the management with some basis for comparison of standards of production. It would be unintelligent, of course, to expect overseers to bring down their costs per unit to the lowest figure for the whole estate because costs of certain operations in adjoining sections will often differ appreciably through causes which are not difficult to see. In addition, reduction of immediate expenses by the cutting down of necessary work should not be countenanced, because, on account of subsequent yield reduction or other expense, it really amounts to an increase of cost.

Records should also be kept of the utilisation of locomotives, rolling stock, animals, mechanical implements and other such types of fixed capital. At first, the actual time during which the item has been used can be compared with the time which it could have been used. By studying the relations of these proportions in connection with the general and special features of the estate, some re-arrangement may be adopted with a view to the maximum utilisation of the item. One estate, by keeping detailed records of the utilisation and location of its rolling stock has been able to cope with a progressively increasing demand for transport by a much less than proportionate increase in the amount of that rolling stock.

Questions of the substitution of an implement for labour or animals, or of one implement for another, are often likely to arise, and a reasonably accurate system of costing is the most sure test of the relative merits of two different methods of doing the same thing. To take an example, tests were recently being made on an estate to find out whether a light tractor was more economical than animal ploughing over difficult and uneven land.

From the economist's and investor's point of view, it would be of great interest to have comparisons of the cost of production on estates of different size. From these costs some reasonable estimate might be made of the most economic size of the business unit in the sugar industry—the size at which the returns would be more than proportionately decreased by an increase or decrease on that size, consequently the size at which cost per unit would be a minimum. Such a study might show that the industry would be best split up into say three branches, cane farming, manufacturing of raw s gar, and refining. Take

the second branch. At present all types of factory are in existence from the one still evaporating juice in open pans to the large central, and these often operate within a few miles of each other. The aggregation of small industrial units into fewer larger units and in many cases into one large unit has been the keynote of economic evolution in many countries during the present century, and this has been dictated mostly by the economies of large-scale production. The United States Steel Corporation found that it paid to buy up steel works and to close some of them down—they could get the same total production from those remaining in operation.

It may be that this could be done in the sugar industry and the economies to be got from larger and fewer units are worth consideration. For this purpose a compilation of comparative costs of operations in factories of different sizes would be useful. To overcome the strong individuality of most plantation owners and managers, the advantages of amalgamation would have to be clearly shown and to be appreciable. It must not be assumed that a very large factory is necessarily more economical than a smaller one for it often happens that the larger the unit the greater are the difficulties of management and the larger is overhead cost. The most economical size of the business unit is thus another problem for investigation by the method of costing.

Between factory and field there is room for co-operation and this would be more insistent if cane farming and manufacture were carried on separately. The cultivator is interested in keeping his cutting gangs together for continuous work and the factory manager is interested in seeing that no more cane comes into the yard than can be disposed of. By a little more attention to co-ordination it should be possible to arrange supply to suit the requirements of the factory and, when unpredictable stoppages occur, to find alternative employment for the temporarily unemployed cutters; they would by this means be kept together.

From what has been said above it will have been seen that the advantages arising from a costings system do not come entirely from their financial side; the records of the amount, place, and time of work also give information which is valuable to the manager for purposes of organisation, while from the point of view of the industry as a whole, information derived from costs on enterprises of different sizes, gives a basis for deciding the most efficient form of organisation.